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Stream Transport and Agricultural Runoff of Pesticides for Exposure Assessment A Methodology. Part B. Appendices G through K

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16. ABSTRACT

To predict the potential environmental or human health risk posed by agricultural pesticides, exposure assessments require the estimation of chemical concentrations in field runoff and in associated streams. In this report, a methodology is described for estimating the mean, maximum, frequency, and duration of pesticide concentrations, and the maximum daily pesticide runoff and its frequency for various agricultural crops and regions across the country. The Stream Transport and Agricultural Runoff of Pesticides for Exposure Assessment Methodology (called STREAM for convenience of reference) is designed for screening level analyses to provide the order-of-magnitude accuracy appropriate for exposure assessment with minimal investment in time and resources. The specific crops included in STREAM are corn, soybeans, cotton, wheat, and sorghum. Two major crops are considered in four agricultural regions--Southeast, Mississippi Delta, Eastern Cornbelt and Western cornbelt. Incorporated in STREAM is the Hydrological Simulation Program--FORTRAN, a comprehensive watershed hydrology and water quality model that analyzes pesticide fate. The user of STREAM is required to evaluate only the crops and regions of interest, the pesticide application rate, and three pesticide parameters--organic carbon partition coefficient, soil/sediment decay rate, and solution decay rate--in order to obtain pesticide loadings and concentrations.

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Part B--Appendices G through K

by

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At Anderson-Nichols, Mr. Dan Meier was Project Engineer on this task of applying HSPF to the Little River Basin. He was responsible for data base preparation, model calibration and report preparation under the general guidance and review of the Project Manager, Mr. Anthony Donigian. Mr. Mark Hersh

assisted in data preparation tasks, and Mr. Douglas Beyerlein provided guidance in general model application and calibration. Ms. Susan Reutter-Harrah directed the final preparation of the document with text editing performed by Ms. Arinthia L. Jones and with figures and charts prepared by Ms. Marythomas Hutchins. The dedication and efforts of these individuals contributed to the success of this study and is sincerely appreciated.

SECTION 1

INTRODUCTION AND EXECUTIVE SUMMARY

The application of HSPF to the Little River Basin was undertaken as part of the parent study, described in the body of this report, to develop procedures for estimating the likely magnitude and variability of instream pesticide concentrations and pesticide runoff from cropland in selected agricultural regions of the U.S. The overall approach was to evaluate the characteristics of "representative" agricultural watersheds within each region, perform sensitivity analyses using HSPF for a range of selected chemical properties, and transform the model results into a series of curves for estimating (1) the frequency and duration of pesticide concentrations at a watershed outlet, and (2) pesticide runoff from the associated cropland; to use the curves the only information needed is chemical properties and the chemical application rate. To provide a sound basis for the methodology HSPF was applied to actual watersheds within each agricultural region as a demonstration of its ability to simulate chemical transport processes on agricultural watersheds throughout the country. The Little River Basin was selected as the HSPF application site within the Southeast Region.

1.1 STUDY OBJECTIVES

Within the framework of the study described above, the objectives of the HSPF application to the Little River Basin were as follows:

a. demonstrate the ability of HSPF to model the hydrologic, hydraulic, sediment erosion, and sediment transport behavior of an agricultural watershed characteristic of the Southeast Region;

b. estimate selected model parameters, which are usually evaluated through calibration, as a basis for determining representative parameter values for the region.

Pesticide simulation was not performed as part of this application due to the lack of observed pesticide data for comparison with model results and lack of adequate project resources; however, previous studies with HSPF (Donigian et al., 1983) and with predecessor models (Donigian et al., 1977) have sufficiently confirmed the pesticide simulation capabilities of HSPF for the purposes of this project.

The Little River Basin was selected as an application site because of its location in the Southeast Region, its agricultural land, its status as a research watershed, and the availability of a reasonably adequate data base for model application.

The pesticide assessment methodology developed in the parent study provides a screening-level type analysis with order-of-magnitude accuracy in its predictions. Consequently, a

greater degree of latitude was possible in the needed accuracy of the HSPF calibration than would have been allowable for more detailed and demanding planning, design, or watershed management purposes. Also, resource limitations required restrictions on the level of calibration. However, the model results are consistent with and well suited to the overall objectives and framework of this study.

1.2 REPORT CONTENT

The remainder of this introductory section provides an overall summary of the results of the HSPF application to the Little River Basin, followed by conclusions and recommendations for future improvements in the simulation. The body of this appendix begins with the watershed and study area descriptions in Section 2, and the discussion of available data for modeling in Section 3. Section 4 describes the HSPF representation of the watershed through segmentation of the land area, based on meteorologic, edaphic, and land use characteristics, and segmentation of the stream channel. The approach and results of the calibration/verification exercise is then described in Section 5.

1.3 SUMMARY OF RESULTS

The Little River Basin used in this study is located in south central Georgia and has a drainage area of 334.3 sq. km (129.1 sq. mi.). Approximately 35% of the basin is used for cropland and another 25% is in pasture and other agricultural uses. The remaining area is largely forested. The Little River Watershed was chosen for this study because of its representative agricultural use and its complete and accurate meteorologic and streamflow records.

HSPF was used to simulate the flow and sediment transport processes in the Little River Basin. The final set of model parameters (with minor modifications) was then used to represent the Southeast Region.

The hydrologic response of the watershed was calibrated by comparing simulated streamflow with observed flow records for the entire watershed and for three subwatersheds over a 4-year 2-month period; parameters were adjusted until an acceptable match was obtained. Comparisons of simulated and observed annual volumes and peak flows, and flow frequency duration analyses were performed with good to very good results. The final hydrologic parameter set was verified over a 5-year period and produced equally good results.

Soil erosion parameters were calibrated by comparing simulated annual sediment washoff to annual gross erosion estimates for various land uses in the Little River Basin over the 4-year 2-month period. Instream sediment transport was calibrated by comparing simulated sediment concentrations to limited observed concentration data. Concentration comparisons were made in the form of frequency duration curves. Due to the scarcity of accurate observed sediment data, rigorous comparisons were impossible. Overall, the sediment calibration was considered fair to good, based on a general understanding of stream behavior in the region. The final sediment parameter set was verified over a 5-year period and provided results similar to those of the calibration period.

1.4 CONCLUSIONS AND RECOMMENDATIONS

Although the calibration was considered successful, two aspects of the simulation could be improved. First, gross representation of precipitation over the basin using three raingages could not consistently reproduce runoff caused by localized thunderstorms common in the watershed. A greater number of meteorologic and pervious land segments would be required to improve the representation of rainfall over the basin.

Secondly, a lack of accurate observed sediment data severely limited the calibration of sediment transport processes. Additional data is needed to insure accurate representation of sediment washoff from various land uses. A larger number of instream concentration samples taken over a wider range of flow levels is required to better approximate the frequency distribution of suspended sediment concentrations.

SECTION 2

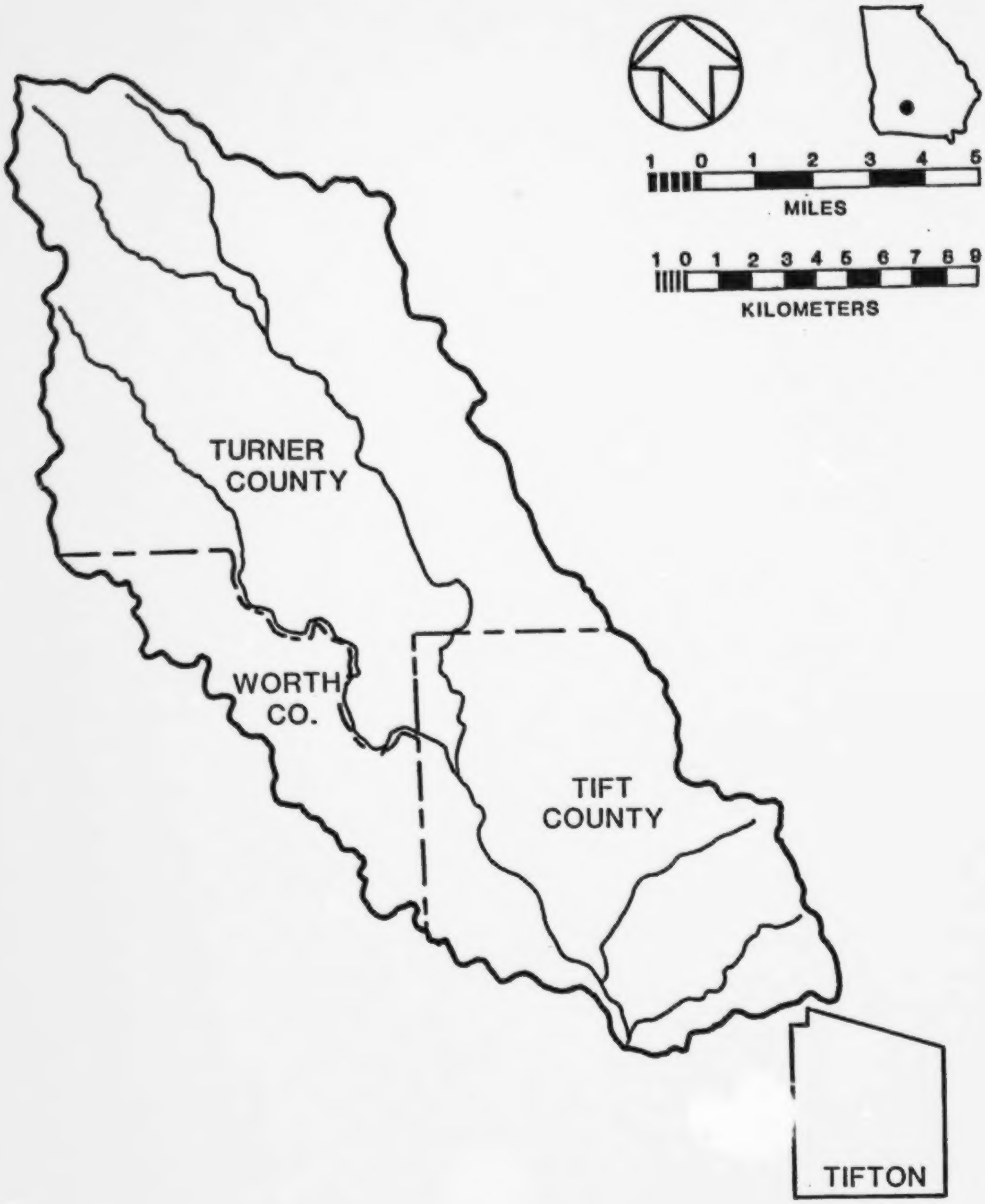
WATERSHED DESCRIPTION

2.1 LOCATION, SIZE, AND SURFACE PHYSIOGRAPHY

The Little River Research Watershed is located in the southern Coastal Plain physiographic province in Tift, Turner, and Worth counties in south central Georgia (Figure 2.1). The Little River flows south to the Withlacoochee River, then to the Suwannee River which empties into the Gulf of Mexico west of Gainesville, Florida.

The basin used in this study has a drainage area of 334.3 sq. km (129.1 sq. mi.) as defined by the most downstream point having recorded streamflow data sufficient for modeling purposes.

The watershed is in an area of floodplains, river terraces, and gently sloping uplands. The basin drains to the south, with elevations ranging from 152 m (500 ft) above MSL in the north to 76 m (250 ft) above MSL in the south, near Tifton. Wide, nearly level, gently sloping divides separate broad, nearly level valley bottoms. Upland slopes are mostly less than 5%, though some valley side slopes range from 5 to 15%.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KILOMETERS
TURNER COUNTY
WORTH CO.
TIFT COUNTY
TIFTON

Figure 2.1 Little River Research Watershed, Georgia.

Lowland slopes range from 0 to 2% (Batten, 1978).

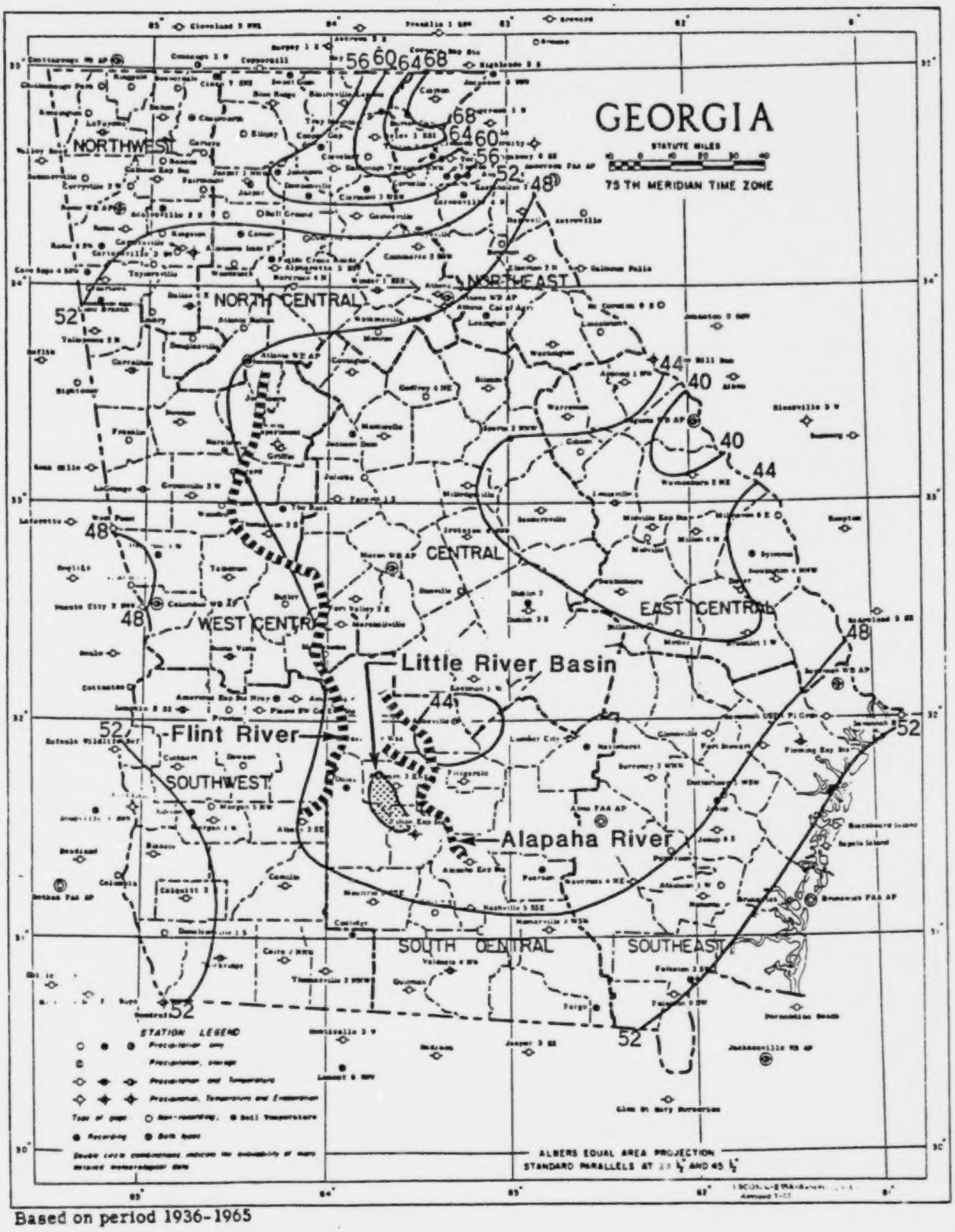
Low-gradient, poorly-defined channels flow through heavily-vegetated, swampy, alluvial floodplains which are covered with water for much of the year. The channel system has a dendritic pattern with the major tributaries flowing relatively parallel to one another (Yates, 1978).

2.2 CLIMATE

The climate of the Little River Basin is characterized by long, hot, humid summers and short, mild winters. The average annual monthly air temperature is 19.2 deg. C (66.6 deg. F) with average monthly temperatures ranging from 11 deg. C (52 deg. F) for January to 27 deg. C (81 deg. F) for July and August. Freezing temperatures occur between mid-November and mid-March but hard freezes and snowfall are rare. The average frost-free season is 253 days (Batten, 1978).

Mean annual precipitation for the basin varies from approximately 112-122 cm (44-48 in.) as shown in Figure 2.2. Average annual precipitation at Tifton is 120.3 cm (47.36 in.) with average monthly rainfall ranging from 5.1 cm (2.0 in.) for November to 14.5 cm (5.7 in.) for July. The wettest months are March, June, July, and August; the driest months are October and November. Localized thunderstorm activity is common in the region.

Average annual pan evaporation at Tifton is 140.9 cm (55.46 in.) with monthly averages ranging from 5.23 cm (2.06 in.) for December to 18.11 cm (7.13 in.) for May (Batten, 1978). Solar radiation varies from an average 263 langley/day in January to 562 langley/day in June (DelVecchio et al., 1982).


GEORGIA
STATUTE MILES
75TH MERIDIAN TIME ZONE
NORTHWEST
NORTH CENTRAL
NORTHEAST
WEST CENTRAL
CENTRAL
EAST CENTRAL
SOUTHWEST
SOUTH CENTRAL
SOUTHEAST
Little River Basin
Flint River
Alapaha River
56
60
64
68
52
48
44
40
STATION LEGEND
ALBERS EQUAL AREA PROJECTION
STANDARD PARALLELS AT 29 ½° AND 45 ½°

Based on period 1936-1965

Figure 2.2 Mean annual precipitation (in.) and NWS meteorological stations of Georgia (U.S. Weather Bureau, 1960; 1980).

2.3 SOILS AND GEOLOGY

The soils in the Little River Basin are predominantly sandy and can be divided into two basic groups in terms of their hydrologic properties. The upland areas are covered with well-drained loamy sands; the lowland areas and drainage ways are very swampy and are covered with poorly drained loamy sands which contain larger accumulations of organic matter than the upland soils (Jensen et al., 1959; Batten, 1978; Calhoun, 1981).

The predominant upland soil series are the Tifton, Fuquay, and Dothan series. These soils consist of deep, well drained, moderately permeable loamy sands that formed mainly in loamy marine sediment. They occur on uplands along hillsides and ridgetops (Calhoun, 1981).

The predominant lowland soil series are the Alapaha, Kinston, and Osier series. The Alapaha series consists of deep, poorly drained, moderately slowly permeable loamy sand that formed in sandy and loamy marine sediment. These soils occur in drainage ways and depressions. The water table is 0.3-0.6 m (1-2 ft) below the surface during winter and spring. Kinston and Osier soils typically occur near each other on floodplains. Kinston soils consist of deep, poorly drained, moderately permeable sandy loams. The water table is often less than 0.3 m (1 ft) from the surface from late fall to early summer. Osier soils consist of deep, poorly drained, rapidly permeable sandy loams. The water table is within 0.3 m (1 ft) of the surface from late fall to early spring (Calhoun, 1981).

Some properties of these particular soil types are given in Table 2.1.

The Little River Basin lies in the outcrop area of the Miocene series, Hawthorn Formation. This formation consists of limestones which form the Floridian aquifers. A shallow ground-water table exists throughout the basin 0-5.8 m (0-19 ft) in depth. This seasonally dependent aquifer dries up during the drier portion of the year (Batten, 1978).

2.4 LAND USES AND MANAGEMENT

The Little River Basin is located in one of the important agricultural regions of the country. Approximately 36% of the study watershed is in crops, 18% in pasture, 40% in forest, and the remaining 6% in wetlands, lakes, roads, and residential and commercial areas (Asmussen, 1982b). Table 2.2 lists the areas of the various land uses in the basin.

The major agricultural crops grown in the basin are corn, soybeans, and peanuts, with smaller acreages in tobacco, cotton, and various vegetables. The various crops are uniformly distributed throughout the watershed with an average field size of 16 ha (40 ac.) (Slack et al., 1980). Croplands are typically located on the well drained upland areas of the basin. Typical tillage practices for major crops are listed in Table 2.3 and are discussed below.

Corn is planted in 91 cm (36 in.) rows in early March. After 6 to 8 weeks the leaves are touching though the canopy coverage is not 100% complete. As the crop matures, "drydown" occurs and the leaves begin to drop. The corn is harvested in October and November. The fields are disced in November and a

TABLE 2.1 PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN THE LITTLE RIVER BASIN
(Source: Calhoun, 1981)

Soil Name	Depth	Permeability	Available Water Capacity	Soil Reaction	Shrink-swell Potential	Erosion Factors	
						K	T
	in	in/hr	in/in	pH			
			Upland				
Dothan	0-14	2.0-6.0	0.06-0.10	4.5-5.5	Very low	0.20	4
	14-42	0.6-2.0	0.10-0.14	4.5-5.5	Low	0.28	
	42-60	0.2-0.6	0.08-0.12	4.5-5.5	Low	0.28	
Fuquay	0-26	>6.0	0.04-0.09	4.5-5.5	Low	0.20	5
	26-31	0.6-2.0	0.12-0.15	4.5-5.5	Low	0.20	
	31-65	0.06-0.2	0.10-0.13	4.5-5.5	Low	0.20	
Tifton	0-10	6.0-20	0.03-0.08	4.5-5.5	Low	0.05	4
	10-15	6.0-20	0.08-0.12	4.5-5.5	Low	0.24	
	15-38	0.6-2.0	0.12-0.15	4.5-5.5	Low	0.24	
	38-65	0.6-2.0	0.10-0.13	4.5-5.5	Low	0.17	
			Lowland				
Alapaha	0-28	6.0-20	0.05-0.08	4.5-5.5	Low	0.15	-
	28-46	0.6-2.0	0.10-0.13	4.5-5.5	Low	0.24	
	46-70	0.2-0.6	0.08-0.10	4.5-5.5	Low	0.28	
Kinston	0-6	2.0-6.0	0.13-0.19	4.5-6.0	Low	0.24	5
	6-44	0.6-2.0	0.14-0.18	4.5-5.5	Low	0.32	
	44-62	-	-	-	Low	-	
Osier	0-6	6.0-20	0.10-0.15	4.5-6.0	Low	-	-
	6-12	6.0-20	0.03-0.10	4.5-6.0	Low	-	
	12-65	>20	0.02-0.05	4.5-6.0	Low	-	

TABLE 2.2 LAND USE AREAS IN THE LITTLE RIVER BASIN (Asmussen, 1982)

	Area		
Land Use	ha	ac	%
Crop	11,970	29,580	35.8
Forest	13,275	32,800	39.7
Pasture	5,952	14,710	17.8
Wetland	836	2,066	2.5
Water	635	1,570	1.9
Residential	334	826	1.0
Commercial	134	330	0.4
Roads	301	744	0.9
Total	33,437 (334.3 sq. km.)	82,626 (129.1 sq. mi.)	100.0

TABLE 2.3 TYPICAL TILLAGE PRACTICES FOR MAJOR CROPS IN THE LITTLE RIVER BASIN (Dunn, 1984)

Month	Corn and Soybeans	Peanuts
Jan		
	(Harvest winter wheat), disc, chisel plow	Graze rye grass
Feb		
	Plant	
Mar		
		Moldboard plow
Apr		
		Apply herbicide, plant seeds
May		
		Apply additional foliar herbicides as needed
Jun		
Jul		
Aug		
Sep		
Oct	Harvest	Harvest, mulch debris and spread over soil
Nov	Disc (Optional: plant winter wheat, or rye grass)	Disc, plant rye grass
Dec	(Graze rye grass)	Graze rye grass

crop of winter wheat may be planted. In January and February the wheat is harvested and the fields are disced and chisel plowed to a depth of 36-38 cm (14-15 in.). In place of the wheat, a winter cover of rye grass may be planted and grazed until the spring planting (Dunn, 1984).

The management practices and tillage schedule for soybeans are roughly the same as those for corn.

Peanuts are typically planted in 91 cm (36 in.) rows in April and May following herbicide application. From May to August, additional foliar herbicides are applied as needed. Complete canopy coverage is attained 6 to 8 weeks after planting. The peanuts are harvested in September and October by pulling the entire shallow-rooted plant from the ground, removing the peanuts, mulching the debris and spreading it over the soil. The fields are disced in November and left fallow or planted with rye grass and grazed until February. In March and April the fields are tilled with a moldboard plow to a depth of 25-30 cm (10-12 in.) prior to the spring planting (Dunn, 1984).

Slash pine and longleaf pine are the most common trees in the basin and are planted on some of the abandoned agricultural land. Both coniferous and hardwood trees occur along the swampy valley bottoms, often accompanied by thick riparian undergrowth (Batten, 1978).

Pasturelands are typically located on the well drained upland areas of the basin. They are planted in bahia or bermuda grasses and are grazed year-round (Batten, 1978). There is virtually no tillage; occasionally, dormant pasture land is scarified to a maximum 10 cm (4 in.) depth and reseeded with clover and grass.

Other land uses in the basin consist of wetlands, surface waters, roads, and residential and commercial areas. The wetlands occur mainly in depressions and along the broad, flat valley bottoms. As an integral part of the drainage system, they have a large attenuating effect on runoff and act as settling basins for suspended materials. The wetlands are inundated with water for much of the year. They are heavily vegetated with coniferous and deciduous trees and riparian undergrowth.

There are over 200 small farm ponds 0.1-1.2 ha (1/4-3 ac.) located throughout the watershed, some of which supply water to small irrigation systems for tobacco. These ponds have a negligible attenuating effect on runoff because the hydrologic response of the basin is very sluggish due to the large swampy areas (Asmussen, 1982b). However, these ponds will act as settling basins for eroded sediment from nearby fields.

Roads and residential and commercial areas are not of sufficient extent to have a large impact on the hydrologic and erosion/sedimentation characteristics of the basin.

2.5 WATER RESOURCES

2.5.1 Water Supply

All water in the Little River Basin originates from precipitation. There is no interbasin transfer of surface or subsurface water into (or out of) the watershed.

A shallow ground-water table exists throughout the basin 0-5.8 m (0-19 ft) in depth. This seasonally dependent aquifer dries up during the drier portion of the year (Batten, 1978). Little water is lost to deep seepage due to the relatively impermeable Miocene sediments underlying the basin (Lowrance et al., 1984).

2.5.2 Water Quality

Water quality surveys taken throughout the 1970's showed that quality of streamflow is good based upon standards set by the U.S. Public Health Service (Batten, 1978). As is typical of southeastern streams with drainage areas of less than 520 sq. km. (200 sq. mi.), there is very little suspended sediment in the Little River; most sediment found in these small streams is dissolved (Asmussen, 1982a).

SECTION 3

AVAILABILITY AND SELECTION OF TIME SERIES DATA

3.1 HSPF TIME SERIES DATA REQUIREMENTS

Hydrologic and sediment simulation with HSPF requires the following time series data:

1. precipitation
2. evaporation
3. streamflow (for comparison with simulated results)
4. water temperature
5. sediment (for comparison with simulated results)
6. air temperature
7. wind speed
8. solar radiation
9. dewpoint temperature

Of these, air temperature, wind speed, solar radiation, and dewpoint temperature are all used primarily in HSPF snowmelt calculations. Since snowfall rarely occurs in the Little River Basin, snowmelt was not simulated. Thus, only the first five time series were needed for this simulation.

3.2 AVAILABLE DATA

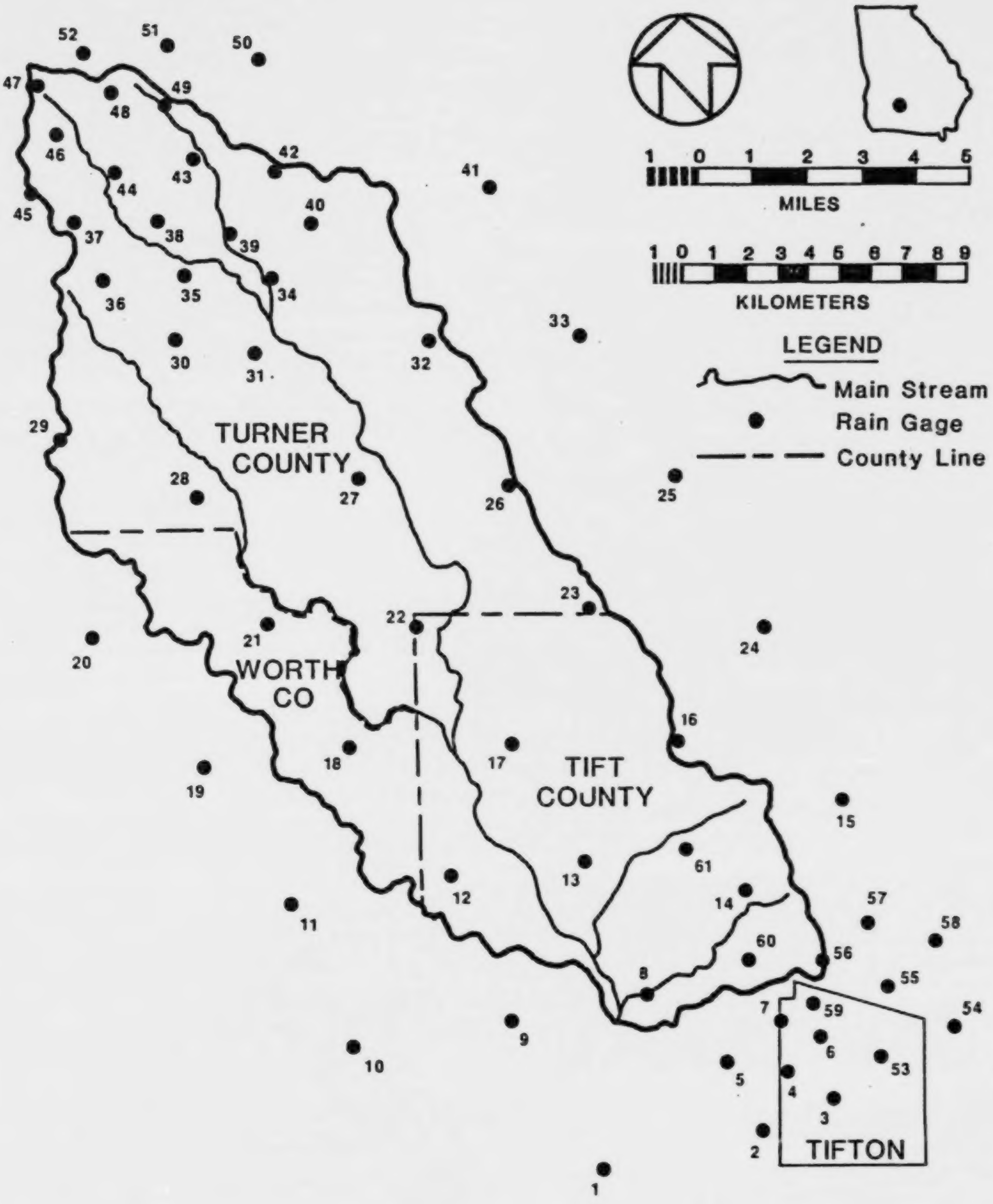
The Little River Basin was selected for the HSPF application because it is representative of many agricultural areas in the southeastern United States and has been extensively gaged for about ten years. The USDA Southeast Watershed Research Laboratory (SEWRL) maintains a network of 54 recording rainfall gages, 8 streamflow gaging stations, and 3 ground-water stage recorders (Batten, 1978).

The locations of the 54 rainfall gages maintained by SEWRL are shown in Figure 3.1 and their periods of record are given in Table 3.1. Cumulative rainfall amounts in increments of 0.1 in. are recorded at 5-minute intervals at each gage and then aggregated to hourly rainfall amounts.

In addition to the SEWRL rain gages, the National Oceanic and Atmospheric Administration (NOAA) maintains a number of meteorologic stations near the Little River Watershed. A partial list of these stations is given in Table 3.2 and a location map is shown in Figure 2.2.

Daily pan evaporation (in inches) was recorded at the Georgia Coastal Plain Experiment Station in Tifton at the southern end of the watershed (Figure 3.1) for the period of July 1948 - March 1981.

The locations of the eight SEWRL streamflow gages are shown in Figure 3.2. Drainage areas and periods of record are given in Table 3.3. Water levels are monitored at 5-minute intervals; from this data, mean daily streamflow (in inches and cubic feet per second) and maximum and minimum instantaneous streamflow (in cubic feet per second) are determined.


MILES
1 0 1 2 3 4 5
KILOMETERS
1 0 1 2 3 4 5 6 7 8 9
LEGEND
Main Stream
● Rain Gage
County Line
TURNER COUNTY
WORTH CO
TIFT COUNTY
TIFTON
1
2
3
4
5
6
7
8
9
10
11
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60
61

Figure 3.1 Location of rainfall gages maintained by the Southeast Watershed Research Laboratory in and around the Little River Basin, Georgia (Burroughs, 1982).

TABLE 3.1 PERIOD OF RECORD INFORMATION FOR SEWRL RAINFALL GAGES (Burroughs, 1982)

Precipitation gage numbers and dates of installation are as follows:

---

1 - 1/24/67
2 - 3/2/67
3 - 1/24/67
4 - 3/2/67
5 - 3/2/67
6 - 3/3/67
7 - 3/3/67
8 - 3/3/67
9 - 3/8/67
10 - 1/24/67
11 - 3/13/67
12 - 3/13/67
13 - 1/23/67
14 - 3/14/67
15 - 1/23/67
16 - 3/14/67
17 - 3/13/67
18 - 1/23/67
19 - 3/16/67
20 - 1/23/67
21 - 3/13/67
22 - 1/20/67
23 - 3/14/67
24 - 3/14/67
25 - 1/20/67
26 - 3/14/67
27 - 1/20/67
28 - 3/15/67
29 - 1/17/67
30 - 1/18/67
31 - 1/18/67
32 - 3/15/67
33 - 1/20/67
34 - 1/19/67
35 - 1/20/67
36 - 1/19/67
37 - 1/16/67
38 - 1/17/67
39 - 1/13/67
40 - 1/19/67
41 - 1/17/67
42 - 1/18/67
43 - 1/17/67
44 - 1/12/67
45 - 1/12/67
46 - 1/19/67
47 - 1/12/67
48 - 1/11/67
49 - 1/11/67
50 - 1/9/67
51 - 1/11/67
52 - 1/11/67
53 - 8/7/69
54 - 8/7/69
55 - 6/6/69
56 - 6/5/69
57 - 7/11/69
58 - 8/8/69
59 - 1/27/71
60 - 9/5/78
61 - 9/6/78

Gages removed were:

1 - 9/1/78
2 - 9/1/78
3 - 9/1/78
4 - 6/5/69
5 - 6/6/69
6 - 1/26/71
7 - 6/3/69

TABLE 3.2 NWS STATION INDEX FOR LITTLE RIVER BASIN METEOROLOGIC DATA (U.S. Weather Bureau, 1980)

Station	Meteorologic Data	Period of Record
Abbeville	P	76
Albany 3 SE	P,T	88
Alma FAA AP	P,T,O	42
Ashburn 3 ENE	P,T	24
Coolidge	P	-
Doles	P	-
Fitzgerald	P,T	57
Hazlehurst	P	-
Moultrie 2 ESE	P,T	51
Nashville 5 SSE	P,T	24
Pearson	P	-
Tifton Exp Station	P,T,E	58
Waycross WSMO	P,T,O	3

P = precipitation
T = daily max-min temperature
E = daily potential evapotranspiration
O = other daily meteorological data (dewpoint temp; wind speed)

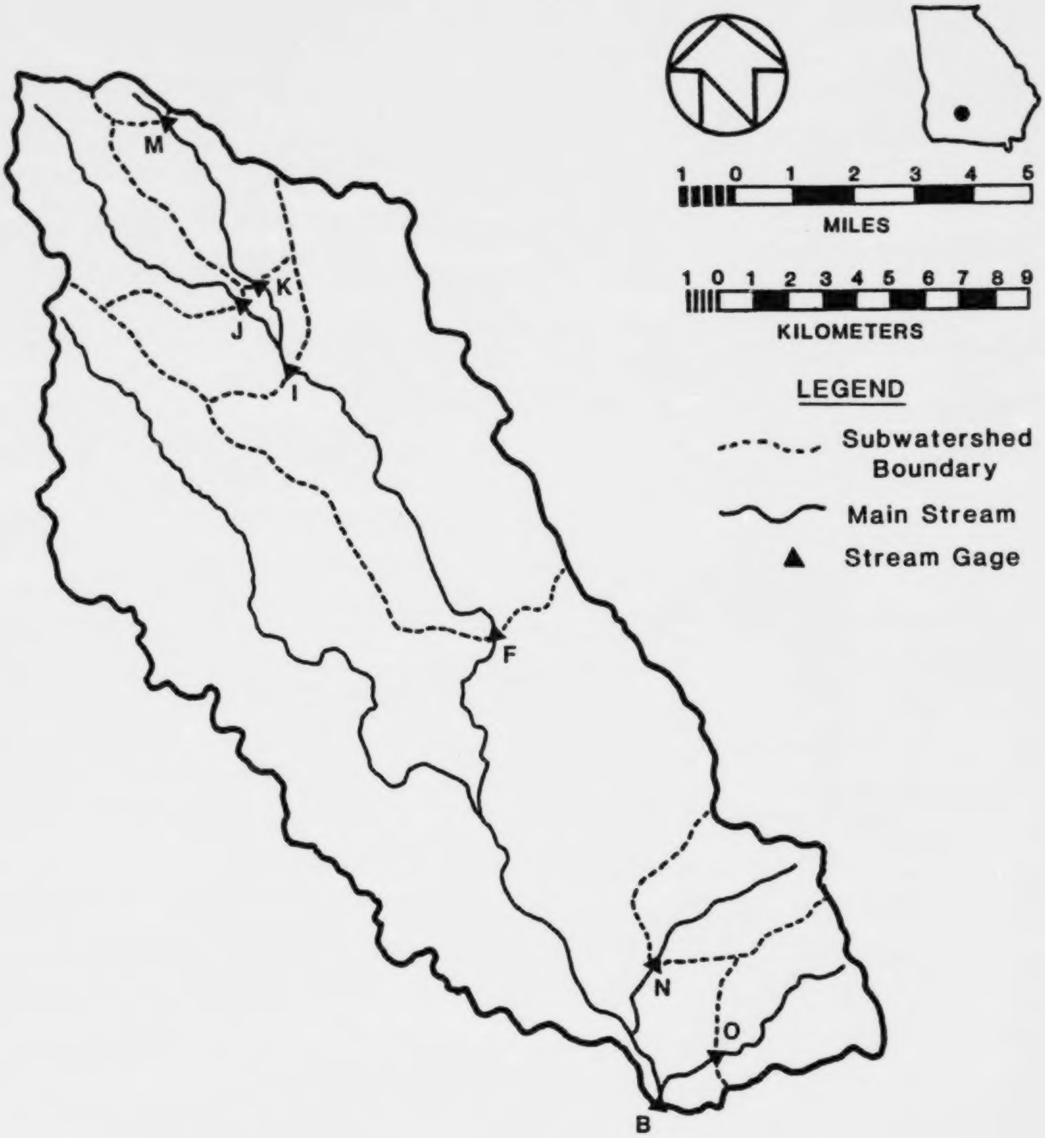

M
K
J
I
F
N
O
B
1 0 1 2 3 4 5
MILES
1 0 1 2 3 4 5 6 7 8 9
KILOMETERS
LEGEND
Subwatershed Boundary
Main Stream
▲ Stream Gage

Figure 3.2 Location of streamflow gages maintained by the Southeast Watershed Research Laboratory in the Little River Basin, Georgia (Batten, 1978).

TABLE 3.3 SEWRL STREAM GAGES IN THE LITTLE RIVER BASIN (Batten, 1978)

Site	Location	Drainage Area sq. km (sq. mi.)	Period of Record
B	Hwy Bridge	334.3 (129.1)	11/71 - Present
F	Hwy Bridge	114.9 (44.4)	1969 - Present
I	Box Culvert	50.0 (19.3)	1968 - Present
J	Box Culvert	22.1 (8.5)	1968 - Present
K	Box Culvert	16.8 (6.5)	1968 - Present
M	Box Culvert	2.7 (1.0)	1968 - Present
N	Box Culvert	15.7 (6.1)	11/70 - Present
O	Box Culvert	15.9 (6.1)	1968 - Present

Available sediment data for the Little River Watershed are limited. Total solids data were collected at all SEWRL streamflow gaging stations from mid-1974 through 1976 as part of a water quality survey conducted by the Southeast Watershed Research Laboratory (Sheridan et al., 1982). Mean total solids concentrations for three-month seasonal periods are available for all stations for this period (Sheridan et al., 1980). However, there is no reliable procedure for converting these total solids data to suspended solids since the solids composition is dynamically changing. Mean seasonal concentrations range from 43 mg/l to 707.4 mg/l.

Total suspended sediment data were collected at several locations in the Little River Basin from January 1979 to April 1981 (Lowrance et al., 1984). Samples were collected at irregular intervals ranging from 15 minutes to seven months. These total concentrations (ppm) were separated into coarse suspended sediment concentrations (particle dia. >2mm) and fine suspended sediment concentrations (particle dia. <2mm). The fine suspended sediment concentrations range from 0 to 25,773 ppm.

Land surface gross erosion estimates are 6.7-13.5 MT/ha-yr (3-6 tons/ac-yr) for corn and soybeans and 13.5-20.2 MT/ha-yr (6-9 tons/ac-yr) for peanuts (Sheridan, 1984). The long-term average soil loss for all non-cropland is 3 MT/ha-yr (1.3 tons/ac-yr) (Lowrance, 1984).

No water temperature data was available for the Little River study basin. However, limited data are available from the USGS for two nearby rivers. The Flint River is located approximately 50 km (31 mi.) west of the Little River and has a drainage area of 13,800 sq. km (5310 sq. mi.) above Albany, Georgia. Water temperature was measured here four or five times per year for the entire simulation period. The Alapaha River is located approximately 30 km (19 mi.) east of the Little River and has a drainage area of 1720 sq. km (663 sq. mi.) above Alapaha, Georgia. Water temperature was measured at this location one to four times per year for the simulation period. Measured water temperatures in these two rivers range from (7 deg. C) 44.6 deg. F in January to (31.5 deg. C) 88.7 deg. in August (USGS, 1980). The locations of these two rivers are shown in Figure 2.2.

3.3 SELECTION OF DATA FOR MODELING

The longest period for which precipitation, evaporation, and streamflow data are available is November 1971 through December 1980. Data for this period were selected for the Little River simulation.

3.3.1 Precipitation

Initially, data from SEWRL rain gages 13, 17, 27, and 38 (Figure 3.1) were inspected because of their central locations within the basin. The 9-year average annual rainfall amounts (for the simulation period 1972-1980) for these gages are all within 3% of each other, though individual yearly rainfall amounts differ by as much as 20%, indicative of the localized thunderstorm activity common in the region. The 9-year averages for gages 13 and 17 differ by only 0.6%; thus, the precipitation over the watershed is adequately represented by gages 13, 27, and 38.

3.3.2 Evaporation

The Little River Basin is approximately 31 km (19 mi.) long north to south. Evaporation should be fairly uniform throughout the basin so the SEWRL data collected at Tifton were used for the entire watershed. The pan evaporation data were adjusted to represent potential evapotranspiration using a pan coefficient of 0.75 (U.S. Dept. of Commerce, 1968).

3.3.3 Streamflow

Of the eight streamflow records available, four of the gages, B, F, I, and N, were used in the calibration (Figure 3.2). Gages B, F, and I are located on the main branch of the Little River. Gage N is located on a small tributary of the Little River in the southern part of the basin. Gage B was selected to enable simulation of the largest possible area. Gages F and I were chosen to calibrate the northern portions of the basin and gage N was selected to represent small agricultural subwatersheds in the southern part of the basin. Of these four gages, the primary emphasis of the calibration was on the two larger watersheds, gages B and F, so as to be more consistent with the other watersheds simulated in this study.

Gage O was not considered because of the possible influence of irrigation practices within the subwatershed on the streamflow record. Irrigation in the rest of the basin is considered to have a negligible effect on streamflow (Asmussen, 1982b).

3.3.4 Sediment

The land surface erosion estimates (Sheridan, 1984; Lowrance, 1984) were used for comparison with simulated annual sediment washoff loads from the various land use types. The suspended sediment data collected from January 1979 to April 1981 (Lowrance et al., 1984) were used for general comparison with simulated instream concentrations. Comparisons were done in the form of sediment concentration frequency curves.

3.3.5 Water Temperature

The USGS data collected at the Flint and Alapaha Rivers were used for the Little River water temperature time series. Preference was given to the Alapaha River data because its smaller drainage area is closer to that of the Little River. The measured values were used as monthly values; values for the intermediate months were interpolated from the measured data.

3.4 QUALITY OF SELECTED DATA

For the 9-year simulation period, hourly precipitation data are missing for the dates listed in Table 3.4. Missing hourly data were filled in using records from the NWS meteorologic station at Doles (Figure 2.2).

The pan evaporation data collected at Tifton are complete for the entire simulation period, as are the four streamflow records chosen for the comparison of simulated and observed

TABLE 3.4 MISSING HOURLY PRECIPITATION DATA AT SEWRL STATIONS

SEWRL Station	Dates of Missing Data	No. of Days
13	3/2/72 - 3/7/72	6
	11/28/76 - 12/10/76	13
	1/3/79 - 1/8/79	6
	6/21/79 - 6/7/79	7
	9/16/80 - 10/7/80	22
	11/19/80 - 12/1/80	13
		67
27	4/30/73 - 5/7/73	8
	9/16/76 - 9/28/76	13
	2/18/78 - 2/28/78	11
	12/20/79 - 1/3/80	15
		47
38	5/3/72 - 5/10/72	8
	5/4/74 - 5/15/74	12
	2/28/79 - 3/6/79	7
		27

flows. (Missing streamflow records were filled in by the SEWRL).

Unfortunately, accurate sediment data is not available for the entire simulation period. The selected data can be used as a general guide for calibration, but are insufficient to provide reliable storm peak and low flow sediment values needed for rigorous calibration and verification tests.

Water temperature data are required by HSPF to simulate the sand transport capability of a river using the Toffaleti method. Small variations in temperature have little impact on this simulation and, furthermore, sand transport is of little importance in this study compared to transport of silt and clay. Thus, the USGS data selected from the nearby Flint and Alapaha Rivers are sufficient for the modeling purposes of this study.

3.5 DATA TIME SERIES SUMMARY

Of the 54 SEWRL rainfall gages, 3 centrally-located gages (13, 27, 38) were selected to represent precipitation over the study basin. The pan evaporation record at Tifton was chosen for the entire basin and was multiplied by a pan coefficient of 0.75 to represent potential evapotranspiration. Four SEWRL streamflow gages (B, F, I, N) were selected for comparison of simulated and observed streamflow. Primary emphasis was placed on gages B and F, which define the largest drainage areas and are thus more consistent with the other watersheds in this study. Water temperature data collected by the USGS at two nearby rivers, the Flint and the Alapaha, were used to simulate sand transport. Limited suspended sediment data collected in the basin were used for comparison with simulated instream concentrations.

SECTION 4

WATERSHED SEGMENTATION FOR HSPF APPLICATION

4.1 PERVIOUS LAND SEGMENTATION

The segmentation of the watershed into separate pervious land segments (PLSs) for simulation by HSPF is based on an evaluation of the following factors:

1. meteorologic patterns
2. soils characteristics
3. land use

4.1.1 Meteorologic Patterns

Although the study basin is not very large, precipitation varies considerably within the watershed due to localized thunderstorms. Three SEWRL rain gages with central locations in the basin were selected. The three precipitation records were weighted based on the areal percentage of the basin that each gage covered. The sum of the three weighted records was applied to the entire basin, resulting in only one meteorologic segment. Thus, there may be small errors for individual storm events but the weighted average of the three gages adequately represents the precipitation in the basin over the 9-year simulation period.

4.1.2 Soils Characteristics

Soils can have a large influence on basin discharge behavior because their properties determine the rates of infiltration, percolation, and interflow, which in turn affect the timing and quantity of runoff. Variability of soils characteristics within a watershed will produce different hydrologic responses from different parts of the basin. Individual pervious land segments should be established to represent these different characteristics.

As noted in Section 2.3, there are two basic soil types in the Little River Basin; the poorly-drained swamp-alluvial soils along the valley bottoms and the well-drained upland soils. Generally, the upland soils are used for cropland and pastureland and the lowland soils are occupied by forests. Segmentation based on land use is discussed below; no additional segmentation was required to account for variations in soils characteristics since different soil types essentially coincide with specific land uses.

4.1.3 Land Use

Different land uses modify the hydrologic response of an area chiefly by the impacts of the different vegetation regimes. The vegetation of an area affects the infiltration, surface detention, interception, and evapotranspiration processes of the hydrologic cycle represented by HSPF.

Table 4.1 provides a listing of land use types for the four calibration watersheds and the percentages of each type with respect to total watershed area. These various land uses can be categorized into three major vegetation types:

1. crops (35.8% of watershed)
2. forest (39.7% of watershed)
3. pasture (and other uses) (24.5% of watershed)

The three major crops are corn, soybeans, and peanuts. Corn and soybeans each occupy approximately 10% of the basin and peanuts (and other crops) are grown on the remaining cropland acreage (approximately 15% of the basin) (Dunn, 1983; Griffeth, 1983). Corn and soybeans are planted and harvested at similar times of the year (USDA, 1972). Initially, corn and soybeans were represented by one pervious land segment but were later divided into two segments to allow subsequent simulation of pesticide application on the individual crop types. The same parameters were used for both crops due to similarities in growing seasons, tillage practices, and canopy development. Peanuts (and other crops) were represented by a third pervious land segment.

Almost 40% of the basin is occupied by forested land, the majority of which occurs along the swampy drainage system. A separate pervious land segment was used to account for the different evapotranspiration and drainage characteristics of this land use. A fifth pervious land segment representing pastureland and all other land uses accounted for the remaining watershed area.

TABLE 4.1 LAND USE IN THE LITTLE RIVER SIMULATION WATERSHEDS (Asmussen, 1982)

Land Use Category	Percent of Watershed Area			
	B	F	I	N
Crop	35.8	32.3	27.1	46.7
Forest	39.7	43.7	54.6	31.1
Pasture	17.8	17.1	16.0	17.3
Wetland	2.5	1.4	0.3	0.2
Water	1.9	1.8	1.0	2.1
Residential	1.0	1.8	0.1	1.7
Commercial	0.4	1.1	0	0
Roads	0.9	0.8	0.9	0.9
TOTAL(%)	100.0	100.0	100.0	100.0
Area, sq. km	334.3	114.9	50.0	15.7
(sq. mi.)	(129.1)	(44.4)	(19.3)	(6.1)

4.1.4 Final Pervious Land Segmentation

Variability in meteorologic patterns necessitates the use of three weighted rain gages in order to perform a reasonable hydrologic simulation. This results in only one meteorologic segment. Figure 4.1 shows the areas represented by each gage used in developing the weighted precipitation record for the segment.

Variations in land use (and the corresponding soils characteristics) were represented by five pervious land segments - corn, soybeans, peanuts (and other crops), forest, and pasture (and other land uses). Table 4.2 lists the segments and the areas of each contributing to the streamflow at the four SEWRL stream gages.

4.2 IMPERVIOUS LAND SEGMENTATION

Because of the low percentage of impervious land area in the basin, no impervious land segments were used in the simulation.

4.3 CHANNEL SEGMENTATION AND NETWORK

Segmentation of a river for simulation by HSPF requires consideration of channel characteristics such as cross-section shape and river bed slope and roughness, entry points of major tributaries, and locations of stream gages used for comparison of simulated and observed flow and sediment.

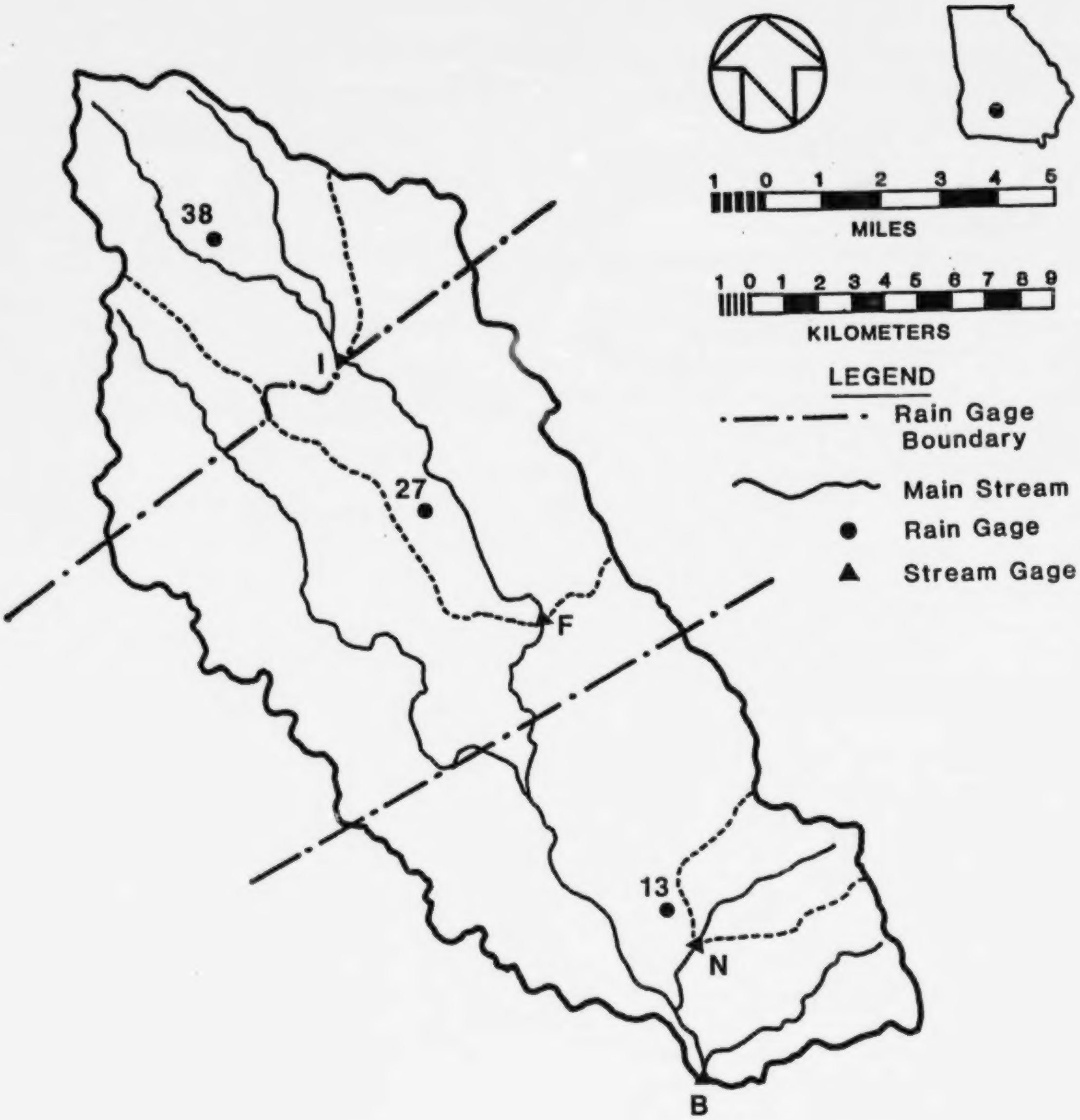

38
27
13
I
F
N
B
1 0 1 2 3 4 5
MILES
1 0 1 2 3 4 5 6 7 8 9
KILOMETERS
LEGEND
Rain Gage Boundary
Main Stream
Rain Gage
Stream Gage

Figure 4.1 Final segmentation plan for the Little River Basin, Georgia.

TABLE 4.2 PERVIOUS LAND SEGMENTS AND AREAS CONTRIBUTING TO STREAMFLOW AT SEWRL STREAM GAGES

		Area sq. km. (sq. mi.)			
		SEWRL Stream Gage			
PERLND	Land Use	B	F	I	N
1	Corn	34.3 (13.25)	9.9 (3.86)	3.6 (1.4)	2.3 (0.9)
2	Soybeans	34.3 (13.25)	9.9 (3.85)	3.6 (1.4)	2.3 (0.9)
3	Peanuts	50.5 (19.5)	17.4 (6.7)	6.5 (2.5)	2.6 (1.0)
4	Forest	133.1 (51.4)	50.3 (19.4)	27.2 (10.5)	4.9 (1.9)
5	Pasture	82.1 (31.7)	27.5 (10.6)	9.1 (3.5)	3.7 (1.4)
Total		334.3 (129.1)	115.0 (44.4)	50.0 (19.3)	15.8 (6.1)

4.3.1 Channel Characteristics

Streams in the Little River Basin are characterized by low-gradient, poorly-defined channels flowing through heavily-vegetated, swampy, alluvial floodplains which are inundated with water for much of the year. The main stem of the river from the upstream drainage divide to the outlet at SEWRL stream gage B is approximately 40 km (25 mi.) long. The average slope of the main stem is 0.14%.

Channel cross-sectional area gradually increases downstream and there are no abrupt changes in river bed slope. Thus, segmentation was performed based on the locations of stream gages and the entry point of a major tributary, Daniels Creek. This segmentation resulted in five reaches which are further described below.

4.3.2 FTABLE Definition

The hydraulic characteristics of each reach must be specified in an FTABLE for use in the HSPF input sequence. FTABLEs specify values for surface area, reach volume, and discharge for a series of selected average depths of water in the reach; intermediate values are interpolated.

A stand-alone computer program was used to generate the FTABLES based on Manning's formula and channel characteristics. This program requires inputs of reach length, upstream and downstream bed elevations, channel bottom and bankfull widths, channel height, floodplain slope, and roughness (i.e., n) values for both the channel and the floodplain.

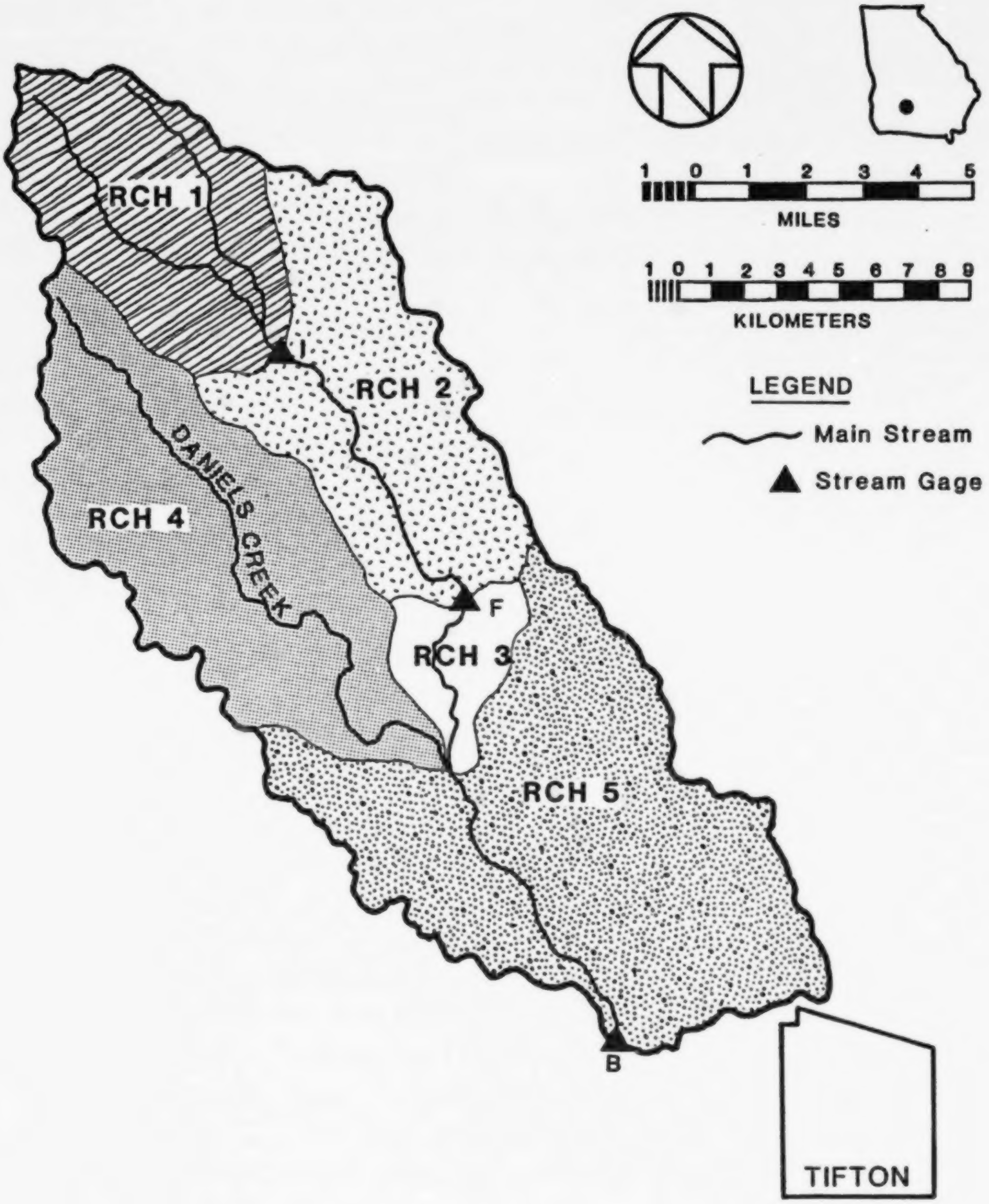
Reach lengths and bed elevations, used for calculating bed slopes, and floodplain slopes were determined from USGS topographic quadrangles. Channel dimensions and Manning's n values were estimated from observations made during field visits since no detailed channel cross-section information was available.

4.3.3 Reach Network Summary

The reach segmentation described above consists of five reaches, four of which are connected in series. The other reach enters the main stem at the top of the most downstream reach. The reaches and their contributing land areas are shown in Figure 4.2. The characteristics of each reach are listed in Table 4.3 and the corresponding FTABLEs are shown in Table 4.4.

4.4 CONNECTIVITY OF LAND SEGMENTS AND STREAM REACHES

The five land uses represented by pervious land segments in the Little River simulation are uniformly distributed throughout the basin. Thus, a portion of each land segment contributes to all five reaches. The areas of the land segments contributing to the individual reaches are listed in Table 4.5.



RCH 1
RCH 2
RCH 3
RCH 4
RCH 5
DANIELS CREEK
I
F
B
TIFTON
1 0 1 2 3 4 5
MILES
1 0 1 2 3 4 5 6 7 8 9
KILOMETERS
LEGEND
Main Stream
Stream Gage

Figure 4.2 River segmentation for the Little River Basin, Georgia.

TABLE 4.3 REACH CHARACTERISTICS OF THE LITTLE RIVER SIMULATION NETWORK

Reach	Length km (mi.)	Average Slope %	Bottom Width m (ft)	Bankfull Width m (ft)	Channel Height m (ft)	Flood-plain Slope %	Channel n	Flood-plain n
1	11.9 (7.4)	0.29	30.5 (100)	61.0 (200)	1.4 (4.5)	2.0	.15	.20
2	11.1 (6.9)	0.09	38.1 (125)	91.4 (300)	1.8 (6.0)	1.0	.15	.20
3	5.3 (3.3)	0.11	45.7 (150)	106.7 (350)	2.1 (7.0)	1.0	.15	.20
4	24.1 (15.0)	0.19	36.6 (120)	91.4 (300)	1.7 (5.5)	1.5	.15	.20
5	11.9 (7.4)	0.05	61.0 (200)	152.4 (500)	3.0 (10.0)	1.0	.15	.20

TABLE 4.4 FTABLES USED FOR THE LITTLE RIVER REACH SIMULATION

```
  FTABLE      1
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .375    97.172   35.0379   10.6121    2397.0
      .750   104.646   72.8788   34.2349    1545.5
     1.125   112.121  113.5227   68.4359    1204.3
     1.500   119.596  156.9697  112.4948    1013.0
     1.875   127.071  203.2197  166.1397     888.0
     2.250   134.545  252.2727  229.3026     798.7
     3.000   149.495  358.7879  384.4218     677.6
     3.750   164.444  476.5153  578.8612     597.6
     4.500   179.394  605.4546  814.1270     539.9
     6.000   313.939  975.4545 1540.2056     459.8
     7.500   448.485 1547.2729 2587.6211     434.1
     9.000   583.030 2320.9092 4042.5054     416.8
  END FTABLE  1

  FTABLE      2
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .500   116.742   55.3220   11.6449    3449.0
     1.000   128.939  116.7424   37.8402    2239.8
     1.500   141.136  184.2614   76.2312    1754.8
     2.000   153.333  257.8788  126.3087    1482.2
     2.500   165.530  337.5947  188.0326    1303.5
     3.000   177.727  423.4091  261.5670    1175.2
     4.000   202.121  613.3334  445.7031    1000.2
     5.000   226.515  827.6516  679.9476     883.7
     6.000   250.909 1066.3635  968.9109     799.0
     8.000   385.455 1902.7273 1929.7803     715.8
    10.000   920.000 3408.1821 3479.5029     711.1
    12.000  1254.545 5582.7275 5831.6260     695.0
  END FTABLE  2

  FTABLE      3
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .583    66.667   36.9445   20.4326    1312.7
     1.167    73.333   77.7778   66.3146     851.5
     1.750    80.000  122.5000  133.4206     666.6
     2.333    86.667  171.1111  220.7737     562.7
     2.917    93.333  223.6112  328.2285     494.6
     3.500   100.000  280.0001  456.0027     445.8
     4.667   113.333  404.4445  774.2512     379.2
     5.833   126.667  544.4446 1179.0433     335.0
     7.000   140.000  700.0002 1677.8164     302.9
     9.333   326.667 1244.4444 3325.4531     271.7
    11.667   513.334 2224.4453 5977.9668     270.1
    14.000   700.000 3640.001510000.2620     264.3
  END FTABLE  3

  FTABLE      4
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .458   245.455  106.2500   14.4015    5356.2
      .917   272.727  225.0000   46.8854    3484.0
     1.375   300.000  356.2500   94.6403    2732.8
     1.833   327.273  500.0000  157.1254    2310.3
     2.292   354.545  656.2500  234.3709    2032.8
     2.750   381.818  825.0000  326.6535    1833.6
     3.667   436.364 1200.0000  558.0002    1561.3
     4.583   490.909 1624.9998  855.0377    1379.8
     5.500   545.455 2100.0000 1222.0413    1247.6
     7.333   989.899 3507.4072 2407.4048    1057.7
     9.167  1434.343 5729.6239 4161.7363     999.5
    11.000  1878.788 8766.6660 6643.1650     958.1
  END FTABLE  4

  FTABLE      5
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .833   201.818  158.8384   32.1761    3583.9
     1.667   224.242  336.3636  104.7501    2331.3
     2.500   246.667  532.5758  211.4392    1828.7
     3.333   269.091  747.4747  351.0340    1545.9
     4.167   291.515  981.0605  523.6021    1360.3
     5.000   313.939 1233.3333  729.7605    1227.0
     6.667   358.788 1793.9395 1246.5798    1044.8
     8.333   403.636 2429.2935 1910.1321     923.3
    10.000   448.485 3139.3940 2729.9941     834.9
    13.333  1046.465 5630.9766 5475.2178     746.7
    16.667  1644.44510115.8260 9914.2852     740.8
    20.000  2242.42416593.941016460.3096     723.1
  END FTABLE  5
```

TABLE 4.5 AREAS OF PERVIOUS LAND SEGMENTS CONTRIBUTING TO STREAM REACHES

Contributing Areas sq. km (sq. mi.)

PLS	Land Use	RCH 1	RCH 2	RCH 3	RCH 4	RCH 5	Total
1	Corn	3.6 (1.4)	6.3 (2.45)	1.3 (0.5)	8.6 (3.3)	14.5 (5.6)	34.3 (13.25)
2	Soybeans	3.6 (1.4)	6.3 (2.45)	1.3 (0.5)	8.6 (3.3)	14.5 (5.6)	34.3 (13.25)
3	Peanuts	6.5 (2.5)	10.9 (4.2)	1.8 (0.7)	14.7 (5.7)	16.6 (6.4)	50.5 (19.5)
4	Forest	27.2 (10.5)	23.1 (8.9)	4.9 (1.9)	33.4 (12.9)	44.5 (17.2)	133.1 (51.4)
5	Pasture	9.1 (3.5)	18.4 (7.1)	3.4 (1.3)	21.7 (8.4)	29.5 (11.4)	82.1 (31.7)
Total		50.0 (19.3)	65.0 (25.1)	12.7 (4.9)	87.0 (33.6)	119.6 (46.2)	334.3 (129.1)

SECTION 5

HSPF CALIBRATION AND VERIFICATION

5.1 OVERVIEW AND SPECIAL PROBLEMS

The calibration process is performed to adjust model parameters so that simulated and observed system outputs agree within some measure of acceptance. Typically, this is accomplished in several stages. The logical order is to calibrate land segment hydrologic processes followed by stream hydraulics in order to properly simulate watershed hydrologic response. Simulated watershed outputs and changes in storage are compared whenever possible to observed values. Next, sediment washoff from the land surface followed by instream sediment process calibration is performed. After the system is calibrated the simulation results are verified by simulating the outputs for a different period of time and comparing them to observed outputs.

The Little River Watershed calibration was performed in the above manner and followed the general procedures discussed in the HSPF Application Guide (Donigian et al., 1984). The results of the hydrologic calibration were evaluated using three main methods: comparison of simulated and observed annual and monthly runoff volumes; comparison of simulated and observed flow frequency curves; and comparison of simulated and observed hydrographs. Following these comparisons several statistical tests, described below, were performed to further evaluate the calibration results. Likewise for the sediment calibration, several comparisons between simulated results and estimated or observed values were made to evaluate the simulation of sediment processes. These included: simulated sediment washoff loads and gross erosion estimates for the various land use types; simulated and observed instream sediment concentrations at the outlet of the basin; simulated and observed frequency curves of the instream concentrations; and the simulated and observed stability of the channel (i.e., degradation or aggradation).

Two special problems were encountered in the Little River simulation. First, simulation of localized thunderstorm activity was not possible due to the use of only three centrally-located rain gages which were combined into one precipitation time series. Thus, runoff produced from localized rainfall not recorded at the gages could not be simulated. Conversely, localized rainfall recorded at one or more of the gages and applied to the entire basin would result in simulated runoff greater than actual runoff. The weighting of the three gages based on areal coverage of the basin minimized these errors and produced an acceptable hydrologic simulation. The second problem was the lack of accurate observed sediment data which severely limited the sediment simulation. Only rough estimates of surface erosion and limited observed instream concentrations were available for general comparisons.

The longest period for which precipitation, evaporation, and streamflow data are available is November 1971 through December 1980. The period of November 1971 to December 1975 was chosen for the calibration and the remaining years, 1976 to 1980, were used for verification. This choice was made based on the greater range of annual precipitation amounts occurring during the earlier years of the simulation period. Proper hydrologic calibration requires a period of record that demonstrates a range of soil moisture and runoff conditions (Donigian et al., 1984).

5.2 HYDROLOGIC/HYDRAULIC CALIBRATION AND VERIFICATION

The initial selection of hydrologic and hydraulic parameters for the Little River simulation was based on guidelines given in the user's manual for EPA's Agricultural Runoff Management (ARM) Model (Donigian and Davis, 1978); information obtained from the Southeast Watershed Research Laboratory (SEWRL) in Tifton, Georgia; Soil Conservation Service soil surveys for Tift and Turner Counties, Georgia; previous experience with HSPF applications; and other miscellaneous sources. Of the four SEWRL streamflow gages used for comparison of simulated and observed flows, the primary emphasis of the hydrologic calibration was on the two larger watersheds, gages B (basin outlet) and F, so as to be more consistent with the other watersheds simulated in this study. For this same reason, a 2-hour timestep was chosen for the simulation interval. Comparisons of model results for 1-hr. and 2-hr. time steps showed that the minor differences could be eliminated with slight adjustments to parameters.

Simulated and observed annual runoff for gages B and F are listed in Table 5.1 for both the calibration and verification periods. Generally, simulated and observed values within 10% of each other is considered a very good simulation. Overall, simulated runoff volumes were very good on a long-term basis

TABLE 5.1 SUMMARY OF SIMULATED AND OBSERVED RUNOFF VOLUMES (cm)

Calibration

	Gage B (outlet)			Gage F		
Year	SIM	OBS	Difference as a % of OBS	SIM	OBS	Difference as a % of OBS
1972	26.2	27.0	-3	26.0	29.3	-11
1973	49.0	46.9	+4	48.7	46.5	+5
1974	37.5	31.1	+21	37.1	34.0	+9
1975	30.3	39.6	-23	29.8	43.1	-31
Total	143.0	144.6	-1	141.6	152.9	-7

Verification

	Gage B (outlet)			Gage F		
Year	SIM	OBS	Difference as a % of OBS	SIM	OBS	Difference as a % of OBS
1976	32.1	37.5	-14	31.9	43.5	-27
1977	37.9	37.4	+1	37.6	34.9	+8
1978	38.5	37.4	+3	38.3	37.3	+3
1979	37.7	33.1	+14	37.4	44.3	-16
1980	31.1	35.4	-12	31.0	37.1	-16
Total	177.3	180.8	-2	176.2	197.1	-11

SIM = Simulated
OBS = Observed

and fair to very good for individual years.

Total runoff for the entire basin (gage B) for the calibration and verification periods was undersimulated by only 1 and 2% of observed values, respectively. Individual annual amounts were undersimulated by 3 to 23% and oversimulated by 1 to 21%. Total runoff at gage F for the calibration and verification periods was undersimulated by 7 and 11% of observed values, respectively. Annual runoff amounts for individual years were undersimulated by 11 to 31% and oversimulated by 3 to 9%.

Table 5.2 shows a water balance for the five land use types for one representative year for each of the calibration and verification periods. The years shown have precipitation amounts close to the long-term average annual rainfall amount. The balances show that subsurface flow is the primary contributor to runoff. This agrees with the findings of on-site studies of subsurface flow in the Little River Watershed (Rawls et al., 1973). Note that surface runoff is a greater percentage of total runoff from forest land compared to the other land uses. This was due to the poorly-drained, swampy soils of the forested areas that are located primarily near the stream channels.

To further evaluate the simulation of runoff volumes, scattergrams of simulated vs. observed monthly flows were plotted. These are shown for both calibration and verification periods in Figure 5.1 for gage B and Figure 5.2 for gage F. In addition, correlation analyses were performed on the mean monthly flow data as well as for mean daily flows and 3-day average flows. Correlation coefficient (i.e.,R-squared) values from these analyses are listed in Table 5.3. A correlation coefficient greater than 0.80 generally indicates good to very good calibration results. Coefficients for mean monthly flows at both gages are greater

TABLE 5.2 TYPICAL ANNUAL WATER BALANCE (CALIBRATION AND VERIFICATION) FOR THE FIVE SIMULATED LAND USE TYPES

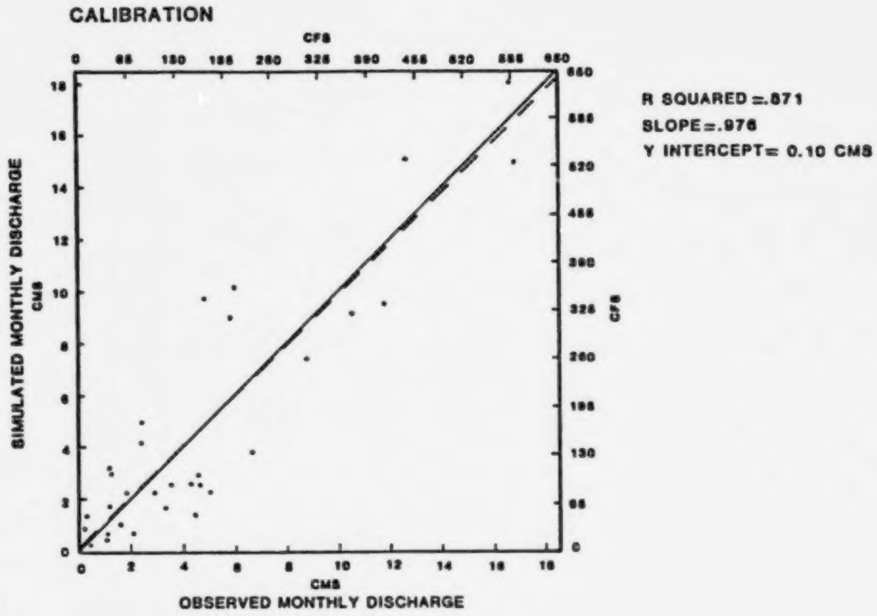
Calibration - 1974

cm	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Peanuts	PLS 4 Forest	PLS 5 Pasture
Precipitation*	131.3	131.3	131.3	131.3	131.3
Evapotranspiration	98.0	98.0	95.3	104.9	84.3
Runoff	35.0	35.0	37.6	29.0	48.8
Surface	3.0	3.0	3.5	13.0	4.6
Interflow	13.2	13.2	14.5	9.7	17.5
Ground water	18.8	18.8	19.6	6.3	26.7

Verification - 1978

cm	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Peanuts	PLS 4 Forest	PLS 5 Pasture
Precipitation*	118.6	118.6	118.6	118.6	118.6
Evapotranspiration	86.1	86.1	84.3	90.4	77.0
Runoff	37.1	37.1	39.1	34.0	46.5
Surface	3.8	3.8	4.6	14.2	4.6
Interflow	14.2	14.2	15.7	10.7	17.5
Ground water	19.1	19.1	18.8	9.1	24.4

* Average annual precipitation at Tifton, GA: 120.3 cm



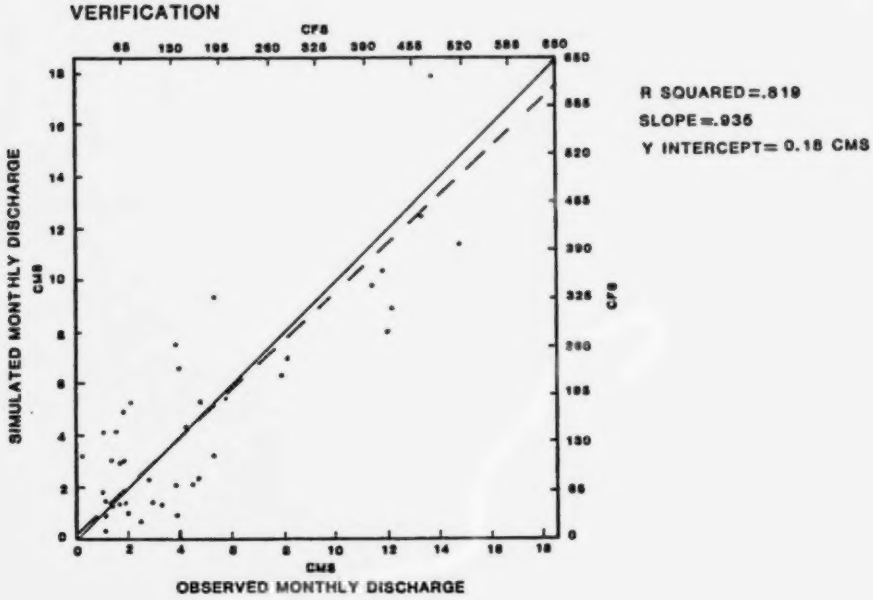


Figure 5.1 Mean monthly flow scattergrams at gage B.

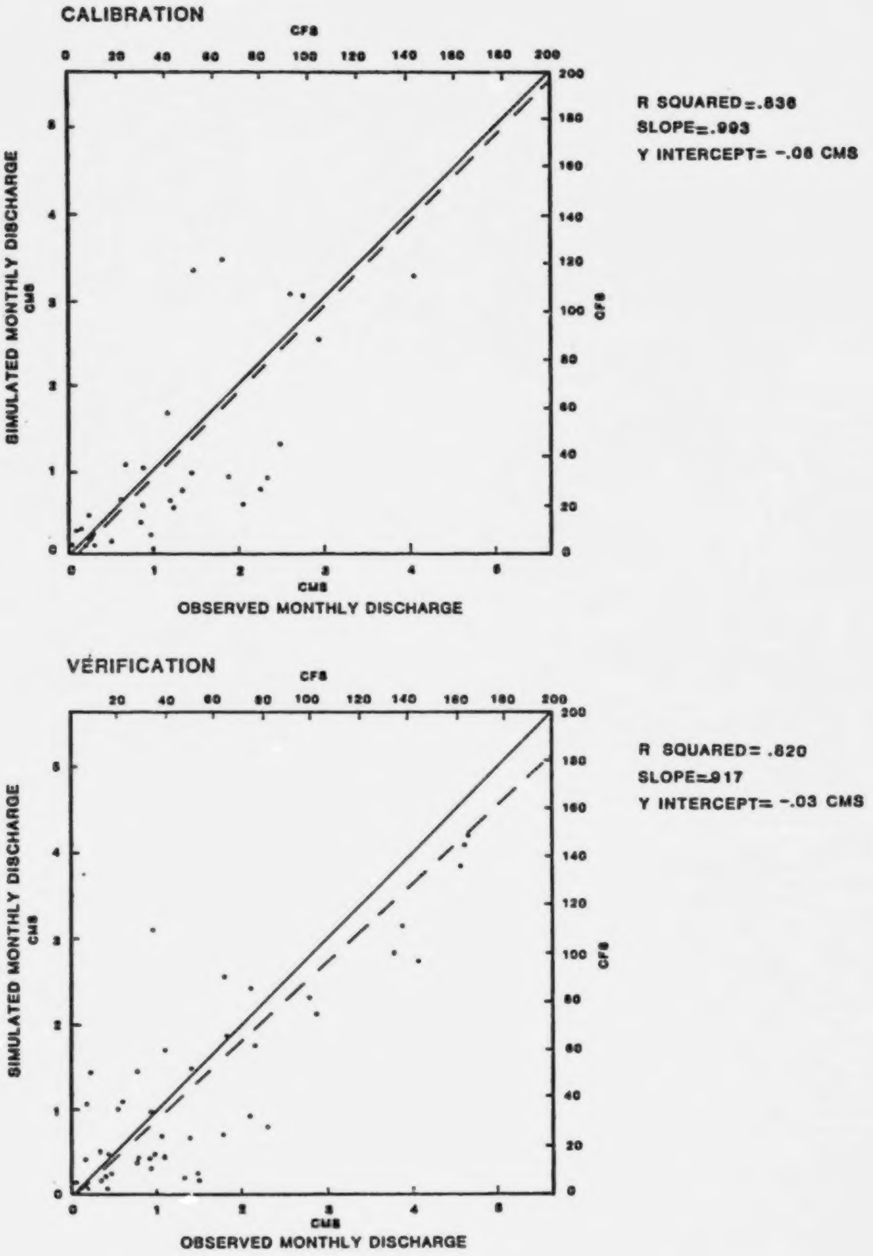


Figure 5.2 Mean monthly flow scattergrams at gage F.

TABLE 5.3 CORRELATION COEFFICIENTS (R-SQUARED) FROM REGRESSION ANALYSES OF STREAMFLOW

Calibration

	R-Squared	
	Gage B	Gage F
Mean daily flows	.826	.765
3-day average flows	.862	.836
Mean monthly flows	.871	.836

Verification

	R-Squared	
	Gage B	Gage F
Mean daily flows	.734	.750
3-day average flows	.806	.810
Mean monthly flows	.819	.820

than 0.81 and as high as 0.87 for the gage B calibration period. A substantial increase in the correlation coefficients from the mean daily flows to the 3-day average flows is an indication that simulated flow magnitudes are fairly accurate but the timing is off by one or two days, particularly for peak flows. At gage B, the entire basin, simulated and observed mean daily flows are also highly correlated for the calibration period. Correlation coefficients for the verification period are also good, though somewhat lower. These results indicate good calibration of monthly runoff volumes for the entire simulation period.

Figures 5.3 and 5.4 show the hydrographs for one water year for the calibration and verification periods for the two gages. Generally, the simulated and observed hydrographs are matched quite well. Several of the simulation problems discussed previously are also evident from the hydrographs. For example, two simulated peaks in early January of 1973 illustrate the effect of localized rainfall. Apparently, precipitation was recorded at one or more of the rain gages which was not representative of rainfall over the entire basin. The result is simulated runoff considerably greater than that which was observed. The opposite problem is illustrated by several small events in June of 1973. Here the gages did not record rainfall which fell on a portion of the basin, resulting in undersimulated runoff. Timing discrepancies between simulated and observed events can also be examined on the hydrographs. Two simulated peaks at gage B in late January of 1978 occur 1 or 2 days before the observed peaks. This situation may be an indication of inaccuracies in reach simulation (e.g., unrepresentative FTABLES), especially if a trend of early or late simulated peaks is apparent, or differences in the timing of rainfall recorded at the gage versus when it fell on the watershed. However, most simulated peaks over the entire Little River simulation period occur on

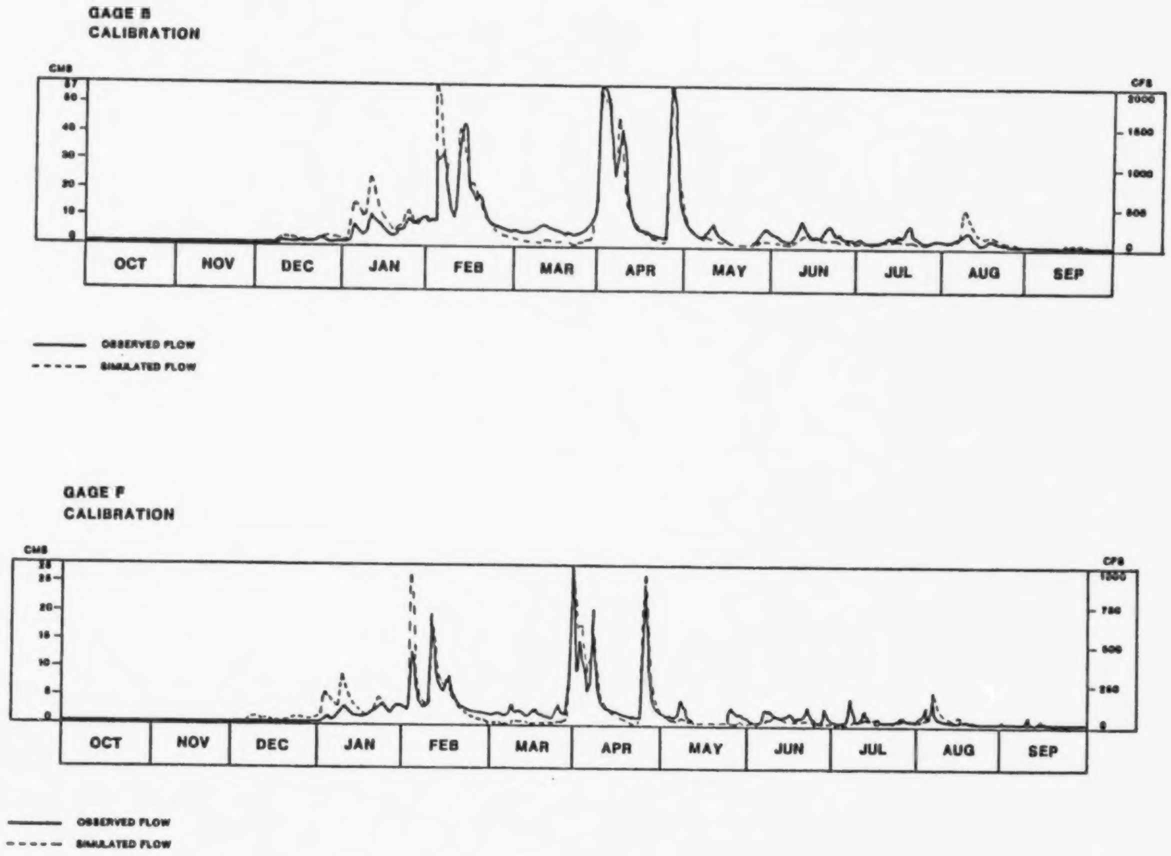


Figure 5.3 Calibration hydrographs at gages B and F for water year 1973.

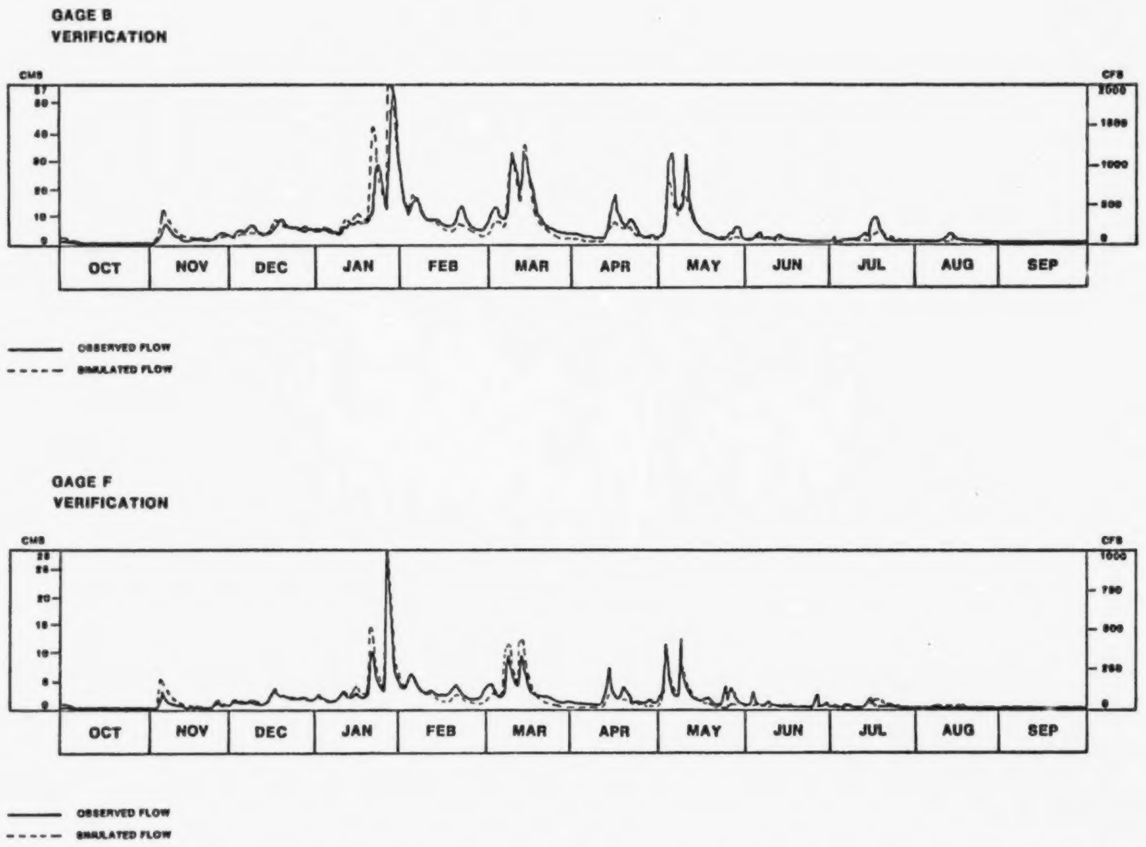


Figure 5.4 Verification hydrographs at gages B and F for water year 1978.

the same day as observed peaks, indicating a good simulation of both runoff and reach hydraulics.

The primary emphasis of the calibration was the accurate simulation of flow frequencies over the 4-year period. Good simulation of flow frequencies is a better indicator of the model's ability to represent watershed hydrologic response than exact simulation of individual observed events. Figure 5.5 shows the simulated and observed flow frequencies at gages B and F for the calibration period. Figure 5.6 shows the same information for the verification period. At gage B, intermediate flows are slightly undersimulated and extreme low flows are somewhat oversimulated. High and intermediate flows (i.e., greater than 5 cms) are simulated very well. This is especially important since these flows are caused by larger precipitation events which result in significant sediment and adsorbed chemical loadings to the stream. At gage F, simulated frequencies are good for the entire simulation period. High and low flows are slightly oversimulated and intermediate flows are somewhat undersimulated. The simulated and observed frequencies for the verification period are better matched than those for the calibration period, indicating that the calibration of flow frequencies was successful. The divergence of the simulated and observed frequency curves in the extreme low flow ranges is not considered significant.

Visual observation indicated that the simulated and observed flow frequency curves were matched reasonably well. The goodness of fit was quantitatively evaluated using a statistical hypothesis testing method, the Kolmogorov-Smirnov (K-S) test of model simulations (Haan, 1977). Though not a rigorous test, the K-S test provides an indication of overall agreement between two cumulative distributions and has been used in past modeling studies (Hartigan et al., 1982; Young

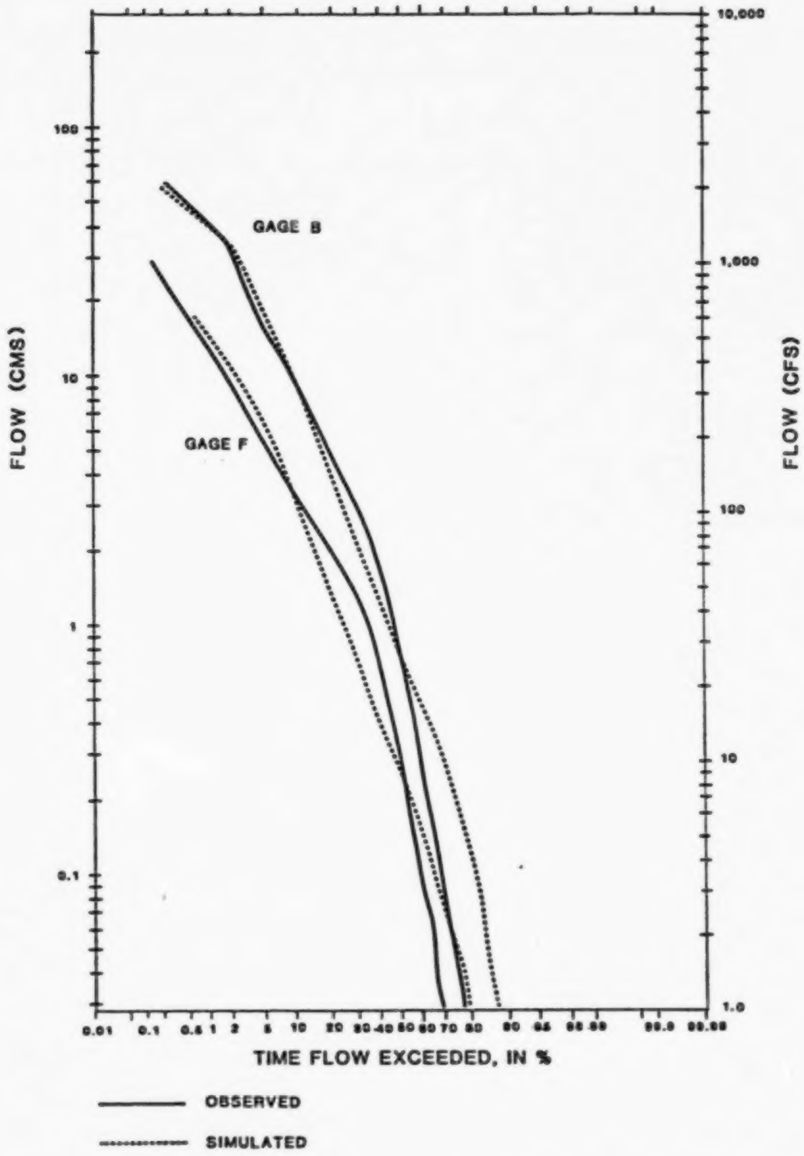


Figure 5.5 Flow frequencies at gages B and F for the calibration period.

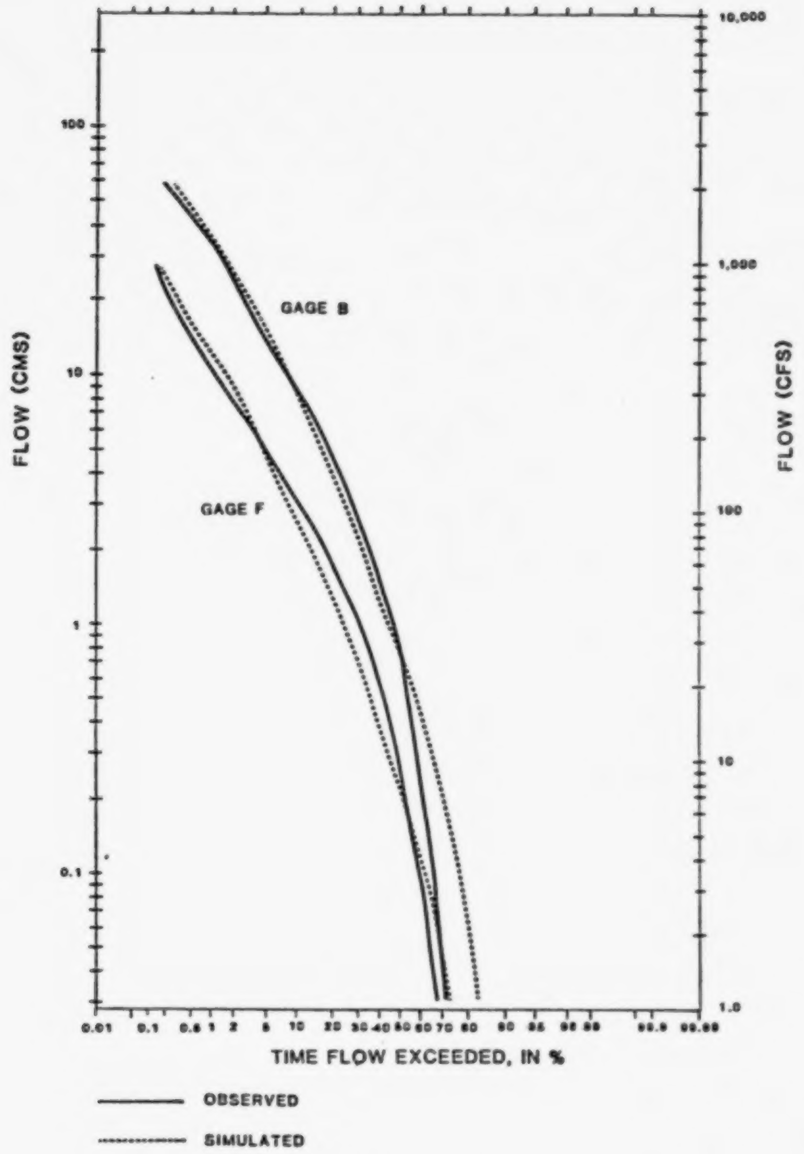


Figure 5.6 Flow frequencies at gages B and F for the verification period.

and Alward, 1983). A basic assumption of the K-S test is that the data are independent of each other within a sample. In the case of daily streamflow, a value on any given day is strongly related to previous values. Autocorrelation analyses of each simulated and observed flow time series were conducted to determine the interval, k, such that every k-th observation out of the entire time series was considered a random sample. The results of the autocorrelation analyses indicated that, for the sample to be independent within the 95% confidence limit, the following intervals, k (in days), should be used:

	Calibration		Verification	
	simulated	observed	simulated	observed
gage B	34	66	58	65
gage F	33	65	56	65

The difference between the cumulative probability densities of the simulated and observed flows should not exceed a critical value, with a given significance level, in order to pass the test. The K-S test results are shown in Table 5.4 for gages B and F for the calibration and verification periods. Streamflow simulation at gage B passed the K-S test at the 10% significance level for both the calibration and verification periods. Streamflow simulation at gage F passed the test at the 10% level for the calibration period and the 1% level for the verification period. These results are a further confirmation of the validity of the simulation of the Little River Watershed.

TABLE 5.4 RESULTS OF K-S TESTS OF STREAMFLOW SIMULATION

Calibration

		D max	
Significance Level	D	gage B	gage F
10%	0.31		
1%	0.42	0.19	0.15
0.1%	0.50		

Verification

		D max	
Significance Level	D	gage B	gage F
10%	0.22		
1%	0.30	0.17	0.24
0.1%	0.36		

The final hydrologic parameters for the five pervious land segments are listed in Table 5.5. The annual ranges of monthly parameters are shown in the table. All parameters are given in English units.

5.3 SEDIMENT CALIBRATION AND VERIFICATION

As mentioned earlier, a major problem with the Little River simulation was the lack of accurate sediment data for comparison with simulated results. General estimates of gross annual average erosion losses and limited observed instream sediment concentration data allowed only general comparisons between simulated and observed outputs.

5.3.1 Edge-of-Stream Sediment Loadings

Estimated erosion losses for the Little River Watershed are 6.7-13.5 MT/ha-yr (3-6 tons/ac-yr) for corn and soybeans and 13.5-20.2 MT/ha-yr (6-9 tons/ac-yr) for peanuts (Sheridan, 1984). The long-term average soil loss for all non-cropland is 3 MT/ha-yr (1.3 tons/ac-yr) (Lowrance, 1984). Table 5.6 lists the simulated annual sediment washoff values for the five pervious land segments for the entire simulation period. Note that a 9-year period is a very short record for developing average annual washoff loads. Erosion loads are extremely variable year to year. Loads estimated by the Universal Soil Loss Equation (USLE) are for a 22-year average when parameters are estimated as per guidelines. Also, note that the estimates are average annual gross erosion loads while simulated loads represent edge-of-stream loadings.

TABLE 5.5 FINAL HSPF HYDROLOGIC PARAMETERS OF THE LITTLE RIVER SIMULATION (English Units)*

PERLND Module - Section PWATER

Parameter	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Peanuts	PLS 4 Forest	PLS 5 Pasture
LZSN	5.0	5.0	5.0	4.0	5.0
INFILT**	0.08-0.13	0.08-0.13	0.08-0.13	0.03	0.1
LSUR	350.	350.	350.	450.	350.
SLSUR	0.05	0.05	0.05	0.02	0.05
KVARY	0.5	0.5	0.5	0.5	0.5
AGWRC	0.92	0.92	0.92	0.96	0.92
INFEXP	2.0	2.0	2.0	2.0	2.0
INFILD	2.0	2.0	2.0	2.0	2.0
DEEPFR	0.0	0.0	0.0	0.0	0.0
BASETP	0.1	0.1	0.1	0.1	0.1
AGWETP	0.0	0.0	0.0	0.3	0.0
CEPSC**	0.02-0.18	0.02-0.18	0.02-0.15	0.2	0.1
UZSN**	0.3-0.7	0.3-0.7	0.3-0.7	1.0	0.7
NSUR**	0.25-0.30	0.25-0.30	0.25-0.30	0.35	0.25
INTFW	2.1	2.1	2.1	1.3	2.1
IRC	0.5	0.5	0.5	0.75	0.6
LZETP**	0.4-0.7	0.4-0.7	0.4-0.6	0.7	0.25

---

* See HSPF User Manual (Johanson et al., 1984) for unit definitions.

** Range of monthly values.

TABLE 5.6 SIMULATED ANNUAL SEDIMENT LOADINGS FROM THE FIVE PERVIOUS LAND SEGMENTS

Calibration

	Sediment Washoff (MT/ha)				
Year	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Peanuts	PLS 4 Forest	PLS 5 Pasture
1972	2.26	2.26	1.39	0.13	0.54
1973	7.31	7.31	7.71	0.28	0.91
1974	6.50	6.50	7.13	0.30	1.08
1975	1.95	1.95	3.63	0.17	0.57
Average	4.51	4.51	4.97	0.22	0.78

Verification

Year	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Peanuts	PLS 4 Forest	PLS 5 Pasture
1976	5.24	5.24	6.25	0.45	1.38
1977	4.89	4.89	5.80	0.28	0.91
1978	4.26	4.26	4.17	0.21	0.60
1979	3.16	3.16	3.85	0.25	0.99
1980	3.12	3.12	3.56	0.13	0.44
Average	4.13	4.13	4.73	0.26	0.86

Vegetation is dense in the floodplain and along cropped areas near the floodplain. Observations in the Little River Watershed indicate that floodplain vegetation acts as a settling area preventing substantial quantities of eroded sediment from reaching the stream channels (Sheridan et al., 1982). Also, the numerous farm ponds in the basin act as settling basins for eroded sediments from adjacent fields, further reducing the sediment actually reaching the stream. Thus, simulated washoff is expected to be somewhat less than the gross erosion from fields.

5.3.2 Instream Sediment Simulation

Limited observed instream sediment concentration data were available for all four calibration stream gages for the period of January 1979 to April 1981. This data only covers the last two years of the verification period. Annual precipitation amounts (based on the three weighted gages) for 1979 and 1980 were 131.8 cm (51.9 in.) and 106.7 cm (42.0 in.), respectively; the mean for these two years is 119.3 cm (47.0 in.). Annual precipitation for the calibration period (1972-5) ranges from 111.0 cm (43.7 in.) to 134.4 cm (52.9 in.) with a mean of 127.8 cm (50.3 in.). Annual rainfall for the verification period (1976-80) ranges from 106.7 cm (42.0 in.) to 141.5 cm (55.7 in.) with a mean of 125.2 cm (49.3 in.). Thus, the mean annual rainfall amounts for the calibration and verification periods are 7 and 5% greater, respectively, than the average annual rainfall for the two years for which sediment data is available. Consequently, simulated instream concentrations are expected to be somewhat greater than the observed values due to larger precipitation amounts. Also, most samples were taken during low and intermediate flow periods with few taken during high flow events; as a result, the data are biased towards lower concentrations.

Simulated and observed sediment concentration frequency curves for gage B are shown in Figure 5.7 for the calibration and verification periods. Data from all four gages are plotted. Simulated concentration frequency curves are similar for the two periods. Low concentrations are somewhat undersimulated and intermediate and high concentrations are considerably oversimulated; the reasons for this are difficult to assess due to the bias in the limited observed data discussed above. The fact that the concentration frequency curves are similar for all four gages is an indication that the channel system is relatively stable. Observations in the Little River Watershed indicate the channels are slowly aggrading (Sheridan, 1984). During a field visit to the watershed, considerable sand deposits were observed along channels and on floodplains. Simulation results mirror this slow aggradation. Table 5.7 shows annual sediment mass balances for the entire simulation period. Note that there is a net deposition to the channel system every year. Simulated changes in bed depth show negligible amounts of scour and deposition. In addition, bed distributions of sand, silt, and clay fractions remain virtually unchanged for the entire simulation period.

The final set of sediment parameters are listed in Table 5.8 for both the land surface (PERLND Module - Section SEDMNT) and the reach system (RCHRES Module - Section SEDTRN). The annual ranges of monthly parameters are shown in the table. All parameters are given in English units except where noted.

In summary, a lack of accurate sediment data hindered the calibration of land surface and instream sediment processes. General comparisons and evaluations were made with limited available data such that the simulation results were considered sufficient for the purposes of this study.

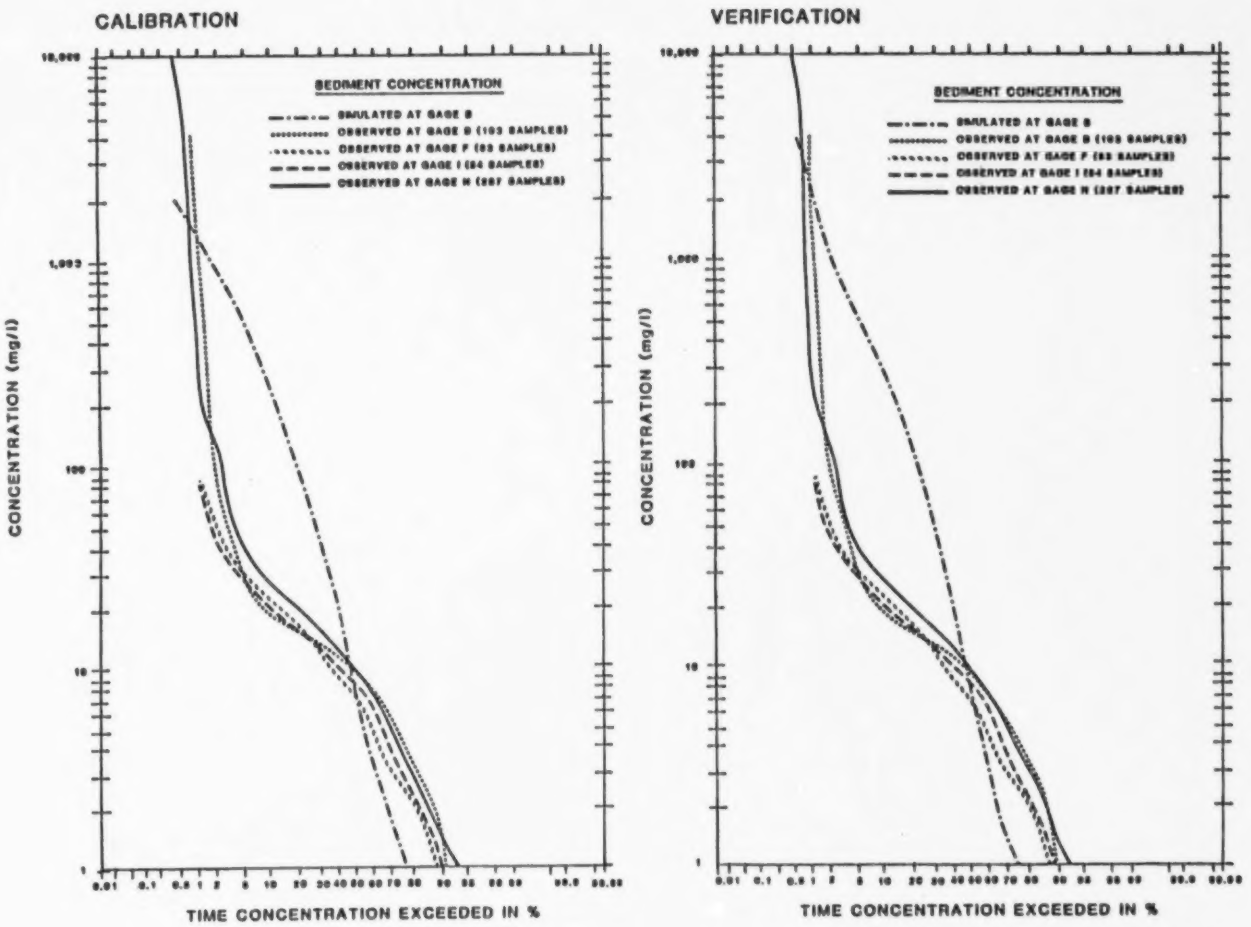


Figure 5.7 Instream sediment concentration frequency curves for the calibration and verification periods.

TABLE 5.7 SIMULATED ANNUAL SEDIMENT MASS BALANCES

Calibration

	Simulated Sediment Loads (MT/ha)		
Year	Total Load at Gage B	Total Load from Land Surface*	Load from Channel System
1972	0.81	0.85	-0.04
1973	2.73	3.00	-0.27
1974	2.47	2.80	-0.33
1975	1.10	1.43	-0.33

Verification

Year	Total Load at Gage B	Total Load from Land Surface*	Load from Channel System
1976	2.22	2.55	-0.33
1977	1.97	2.22	-0.25
1978	1.59	1.75	-0.16
1979	1.46	1.57	-0.11
1980	1.26	1.34	-0.08

*Total Load from Land Surface = (10.3% of basin in corn * sed. load from corn) + (10.3% of basin in soybeans * sed. load from soybeans) + (15.2% of basin in peanuts * sed. load from peanuts) + (39.7% of basin in forest * sed. load from forest) + (24.5% of basin in pasture * sed. load from pasture)

TABLE 5.8 FINAL HSPF SEDIMENT PARAMETERS OF THE LITTLE RIVER SIMULATION (English Units)*

PERLND Module - Section SEDMNT

Parameter	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Peanuts	PLS 4 Forest	PLS 5 Pasture
KRER	0.15	0.15	0.15	0.28	0.32
JRER	2.0	2.0	2.0	2.2	2.2
AFFIX	0.003	0.003	0.003	0.0	0.0
COVER**	0.01-0.75	0.01-0.75	0.01-0.68	0.95	0.85
KSER	10.0	10.0	10.0	3.0	5.0
JSER	1.5	1.5	1.5	1.8	1.8
KGER	0.0	0.0	0.0	0.0	0.0
JGER	1.0	1.0	1.0	1.0	1.0
DETS**	0.5-1.0	0.5-1.0	0.5-1.0	0.05	0.10

RCHRES Module - Section SEDTRN

Parameter**	Sand	Silt	Clay
D	0.01	0.00063	0.000055
W	1.4	0.003	0.000027
RHO (g/cm^3)	2.65	2.2	2.0
TAUCD	-	0.02	0.015
TAUCS	-	0.12	0.1
M	-	0.01	0.006

---

* See HSPF User Manual (Johanson et al., 1984) for units.

** Range of monthly values.

*** Same values for all 5 reaches.

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APPENDIX H

Yazoo River, Mississippi

Watershed Data, Segmentation, and HSPF Calibration/Verification Report

ABSTRACT

The EPA Hydrological Simulation Program - FORTRAN (HSPF) was applied to an upper portion of the Yazoo River Basin in Mississippi as part of the development of a methodology to estimate pesticide runoff and resulting instream concentrations from agricultural cropland in various regions of the United States. The Yazoo River Basin was chosen as representative of watersheds in the Mississippi Delta region. HSPF was calibrated and verified for hydrology, hydraulics, sediment erosion, and instream sediment transport as a basis for performing sensitivity analyses on key pesticide chemical parameters.

This report describes watershed data avaliable for simulation, the segmentation plan for dividing the study area into land and channel segments, and the results of the calibration and verification efforts. In general, this study produced a good to very good hydrologic calibration and verification, and a fair to good sediment simulation. The sediment simulation results could not te completely calibrated and verified due to a lack of sufficient observed sediment data for a rigorous model application. The model results for both hydrology and sediment were considered quite acceptable, however, for the purposes of this study.

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ABSTRACT

To predict the potential environmental or human health risk posed by agricultural pesticides, exposure assessments require the estimation of chemical concentrations in field runoff and in associated streams. In this report, a methodology is described for estimating the mean, maximum, frequency, and duration of pesticide concentrations, and the maximum daily pesticide runoff and its frequency for various agricultural crops and regions across the country. The Stream Transport and Agricultural Runoff of Pesticides for Exposure Assessment Methodology (called STREAM for convenience of reference) is designed for screening level analyses to provide the order-of-magnitude accuracy appropriate for exposure assessment with minimal investment in time and resources.

The specific crops included in STREAM are corn, soybeans, cotton, wheat, and sorghum. Two major crops are considered in four agricultural regions--Southeast, Mississippi Delta, Eastern Cornbelt, and Western Cornbelt.

Incorporated in STREAM is the Hydrological Simulation Program--FORTRAN, a comprehensive watershed hydrology and water quality model that analyzes pesticide fate. The user of STREAM is required to evaluate only the crops and regions of interest, the pesticide application rate, and three pesticide parameters--organic carbon partition coefficient, soil/sediment decay rate, and solution decay rate--in order to obtain pesticide loadings and concentrations.

This report is submitted in partial fulfillment of contract number 68033116 by Anderson-Nichols & Co., Inc., under the sponsorship if the U.S. Environmental Protection Agency. This report covers the period October 1983 to September 1985, and work was completed as of January 1986.

FORMAT OF MANUAL

Documentation of the Stream Transport and Agricultural Runoff of Pesticides for Exposure Assessment Methodology (STREAM) is in two parts. Part A presents the text and appendices A through F. Included is a description of the overall development of STREAM and a detailed discussion of the application procedures; the interpretation and use of results; and the principal assumptions, limitations, and uncertainties in the methodology. Examples of applications of STREAM are provided including step-by-step descriptions of the use of frequency curves and of the required calculations. Appendices A through D present the frequency curves for pesticide solution and bed concentrations, and pesticide loadings for the Southeast, Mississippi Delta, Eastern Cornbelt and Western Cornbelt agricultural regions. Appendix F provides a general description of statistical analysis of time series data to provide the user with background on the development and interpretation of frequency-duration curves and various statistical goodness-of-fit tests used in model calibration and verification. Part B presents appendices G through K containing watershed data, segmentation information, and calibration/verification reports for five application watersheds in Georgia, Mississippi, Iowa, Ohio and Nebraska.

APPENDIX G

Little River, Georgia

Watershed Data, Segmentation, and HSPF Calibration/Verification Report

ABSTRACT

The EPA Hydrological Simulation Program - FORTRAN (HSPF) was applied to the Little River Research Watershed in Georgia as part of the development of a methodology to estimate pesticide runoff and resulting instream concentrations from agricultural cropland in various regions of the United States. The Little River was chosen as representative of watersheds in the Southeast. HSPF was calibrated and verified for hydrology, hydraulics, sediment erosion, and instream sediment transport as a basis for performing sensitivity analyses on key pesticide chemical parameters.

This report describes the watershed data available for simulation, the segmentation plan for dividing the study area into land and channel segments, and the results of the calibration and verification efforts. In general, this study produced a good to very good hydrologic calibration and verification and a fair to good sediment simulation. The sediment simulation results could not be completely calibrated and verified due to lack of sufficient observed sediment data for a rigorous model application. The model results for both hydrology and sediment were considered quite acceptable for the purposes of this study, however.

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The firm of Simons, Li and Associates, Inc. were contracted to provide the input data base for HSPF application. Their contribution included all of the input time series data as well as channel cross-section and suspended sediment data.

Personal communications with people in the Vicksburg, MS office of the U.S. Army Corps of Engineers helped greatly in defining channel characteristics. Information came principally fom Larry Banks, James Arnold, Waylon Hill, and Frankie Griggs.

Personal communications with people in various Soil Conservation Service offices throughout the Yazoo Basin helped to define agricultural practices and describe water detention structure operation for preliminary analysis. Information came principally from Peter Forsythe and Jim Partman.

At Anderson-Nichols, Mr. Peter Jowise was Project Engineer on this task of applying HSPF to the Yazoo River Basin. He was responsible for data base preparation, model calibration and report preparation under the general guidance and review of the Project Manager, Mr. Anthony Donigian. Mr. Daniel Meier and Mr. Mark Hersh assisted in data preparation tasks, and Mr. Douglas Beyerlein provided guidance in general model application and calibration. Ms. Susan Reutter-Harrah directed the final preparation of the document with text editing performed by Ms. Arinthia L. Jones and with figures and charts prepared by Ms. Tomi Hutchins. The dedication and efforts of these individuals contributed to the success of this study and is sincerely appreciated.

SECTION 1

INTRODUCTION AND EXECUTIVE SUMMARY

The application of HSPF to the Yazoo River Basin was undertaken as part of the parent study, described in the body of this report, to develop procedures for estimating the likely magnitude and variability of instream pesticide concentrations and pesticide runoff from cropland in selected agricultural regions of the U.S. The overall approach was to evaluate the characteristics of "representative" agricultural watersheds within each region, perform sensitivity analyses using HSPF for a range of selected chemical properties, and transform the model results into a series of curves for estimating (1) the frequency and duration of pesticide concentrations at a watershed outlet, and (2) pesticide runoff from the associated cropland; to use the curves the only information needed is chemical properties and the chemical application rate. To provide a sound basis for the methodology HSPF was applied to actual watersheds within each agricultural region as a demonstration of its ability to simulate chemical transport processes on agricultural watersheds throughout the country. The Yazoo River Basin was selected as the HSPF application site within the Mississippi Delta Region.

1.1 STUDY OBJECTIVES

Within the framework of the study described above, the objectives of the HSPF application to the Yazoo River Basin were as follows:

a. demonstrate the ability of HSPF to model the hydrologic, hydraulic, sediment erosion, and sediment transport behavior of an agricultural watershed characteristic of the Mississippi Delta Region.

b. estimate selected model parameters, which are usually evaluated through calibration, as a basis for determining representative parameter values for the region.

Pesticide simulation was not performed as part of this application due to the lack of observed pesticide data for comparison with model results and lack of adequate project resources; however, previous studies with HSPF (Donigian et al., 1983) and with predecessor models (Donigian et al., 1977) have sufficiently confirmed the pesticide capabilities of HSPF for the purposes of this project.

The Yazoo River Basin was selected as an application site because of its location in the Mississippi Delta Region, its agricultural land, previous modeling studies, and the availability of a reasonably adequate data base for model application.

The pesticide assessment methodology developed in the parent study provides a screening-level type analysis with order-of-magnitude accuracy in its predictions. Consequently, a greater degree of latitude was possible in the needed accuracy of the HSPF calibration than would have been allowable for more detailed and demanding planning, design, or watershed management purposes. Also, resource limitations required restrictions on the level of calibration. However, the model results are consistent with and well suited to the overall objectives and framework of this study.

1.2 REPORT CONTENT

The remainder of this introductory section provides an overall summary of the results of the HSPF application to the Yazoo River Basin, followed by conclusions and recommendations for future improvements in the simulation. The body of this appendix begins with the watershed and study area descriptions in Section 2, and the discussion of available data for modeling in Section 3. Section 4 describes the HSPF representation of the watershed through segmentation of the land area, based on meteorologic, edaphic, and land use characteristics, and segmentation of the stream channel. The approach and results of the calibration/verification exercise is then described in Section 5.

1.3 SUMMARY OF RESULTS

The Yazoo River Basin covers approximately 34,400 sq. km (2,115 sq. mi.) in the northwest portion of Mississippi. A study area accounting for 16% of the Yazoo Basin was chosen for application of HSPF. Within the study area, approximately 2/3 lies in the old Mississippi River floodplain and 1/3 lies in the relatively steep bluff area along its eastern boundary.

The floodplain, or delta region, is extensively devoted to agriculture. A good characterization of delta region flow and sediment transport processes is required to project basin responses throughout the lower Mississippi Delta Region. HSPF was used to accomplish this goal.

The first step in the simulation process was to calibrate the hydrologic response of the watershed. This was accomplished by making preliminary calibrations on small test watersheds; one located in the delta, the other in the bluff region. Following successful simulation results on these smaller basins, the input parameter sets were applied to appropriate sectors of the study area. Further calibrations were then made to refine input parameters as they applied to the much larger basin.

The next step in the simulation process was to characterize soil erosion and sediment transport through the watershed. Estimates of gross erosion, made by applying the Universal Soil Loss Equation (USLE), were obtained for the study area. The estimates were broken down into components including forest land, pasture land, and crop land. Sediment delivery to the stream channel, as modeled by HSPF, was compared to estimated gross erosion rates and adjusted accordingly.

The hydrologic calibration results were compared to observed measurements made at two sites in the study area, near Lambert and at Swan Lake. Flow frequency duration analyses (Figures 5.4 and 5.5) were performed with good results. Simulated and observed daily hydrographs were compared for the entire simulation period. A good match of storm events was evident, with the exception of three major events that were simulated but not observed. All three oversimulations resulted from thunderstorms falling on a limited area that encompassed one of the two representative precipitation gages used in the HSPF application. When these oversimulated runoff volumes were subtracted, good annual runoff comparisons were made for most of the study period (Table 5.1). Upon completion of calibration over a 3-year period, the input sequence was applied to a 4-year verification period. The combined calibration and verification results are considered to be very good.

The sediment calibration results were compared to observed measurements of suspended sediment made near Lambert and Swan Lake. Sediment samples were taken between March 1973 and February 1976, once every one to two weeks. These grab samples provided a guide for matching simulated loads to the range of values associated with most common flow events, but failed to provide a characterization of the higher loads associated with large storm events. Suspended sediment frequency duration analyses (Figures 5.6 and 5.7) were performed with marginally good results. The frequency of observed data values was too limited for rigorous comparison, so additional qualitative restrictions were imposed. Observed tendencies of the Yazoo stream system indicated that the main channel slowly aggrades while many tributaries from the bluff slowly degrade. This condition was replicated in simulated results (Table 5.6). Streambed particle size composition was also kept relatively stable during the study period. Overall, the sediment calibration was considered satisfactory, based on a general understanding of stream behavior in the region. However, due to the lack of data for comparison, a rigorous calibration/verification could not be completed. Results of the 4-year verification period provided results similar to those of the calibration period.

1.4 CONCLUSIONS AND RECOMMENDATIONS

Although the hydrologic calibration was considered successful, a few problems could not be completely resolved. For selected storm events, problems arose from the relatively gross representation of rainfall distribution across the watershed. This resulted from the use of only two precipitation gages to represent rainfall in the entire study area. Unfortunately, no other gages were located in appropriate locations for better representation. Another problem lay in the inability to completely characterize the retardation of flow by small retention reservoirs in the bluff region and bayous of the delta. This resulted in the falling limbs of simulated hydrographs that were somewhat steeper than those observed. This problem was most evident following large storms. The solution lies in a more detailed characterization of the study area, requiring extra reaches, finer land segment definition, and a better estimate of the runoff detention characteristics of contributing areas. Although these problems exist, a good overall representation of the hydrologic processes in the study area was achieved, consistent with the objectives of this project.

The sediment calibration could not be verified as vigorously as the hydrology calibration, and without additional data further tests could not be made. Additional sediment data is needed to better approximate the frequency distribution of measured suspended sediment values. Erratic slope changes, as found in simulated frequency distributions (Figures 5.6 and 5.7), could be minimized. Overall, no better characterization of naturally occurring events can be made without additional sediment data. The high sediment concentrations associated with large runoff events are not represented in the observed data set and these situations are often most critical to sediment-associated chemical transport. Having produced a good hydrologic representation and a qualitatively reasonable sediment transport representation of the study area, the linking of chemical transport to these mechanisms should provide realistic forecasts of pesticide movement through similar basins.

SECTION 2

WATERSHED DESCRIPTION

2.1 LOCATION, SIZE, AND SURFACE PHYSIOGRAPHY

The Yazoo River Basin (Figure 2.1) lies in the northwest corner of the state of Mississippi and covers an area of 34,387 sq. km (13,277 sq. mi.). The greater Yazoo River is comprised of a main channel stretching 494.8 km (307.5 mi.) from Arkabutla Dam in the north to the Mississippi River at Vicksburg in the south. This main channel is called by different names as its flow is augmented by major tributaries. The northernmost stretch is called the Coldwater River as it leaves Arkabutla Dam. Approximately 87 km (54 mi.) downstream at the confluence with the Little Tallahatchie River, the main stem is called the Tallahatchie River. This name remains until the confluence with the Yalobusha River just above Greenwood. Below Greenwood the main channel is known as the Yazoo River.

The Yazoo Basin has been extensively gaged for meteorologic and hydrologic activity. A small portion of the entire basin was chosen as the study area for hydrologic and sediment simulation (Figure 2.2). The Yazoo Basin study area comprises

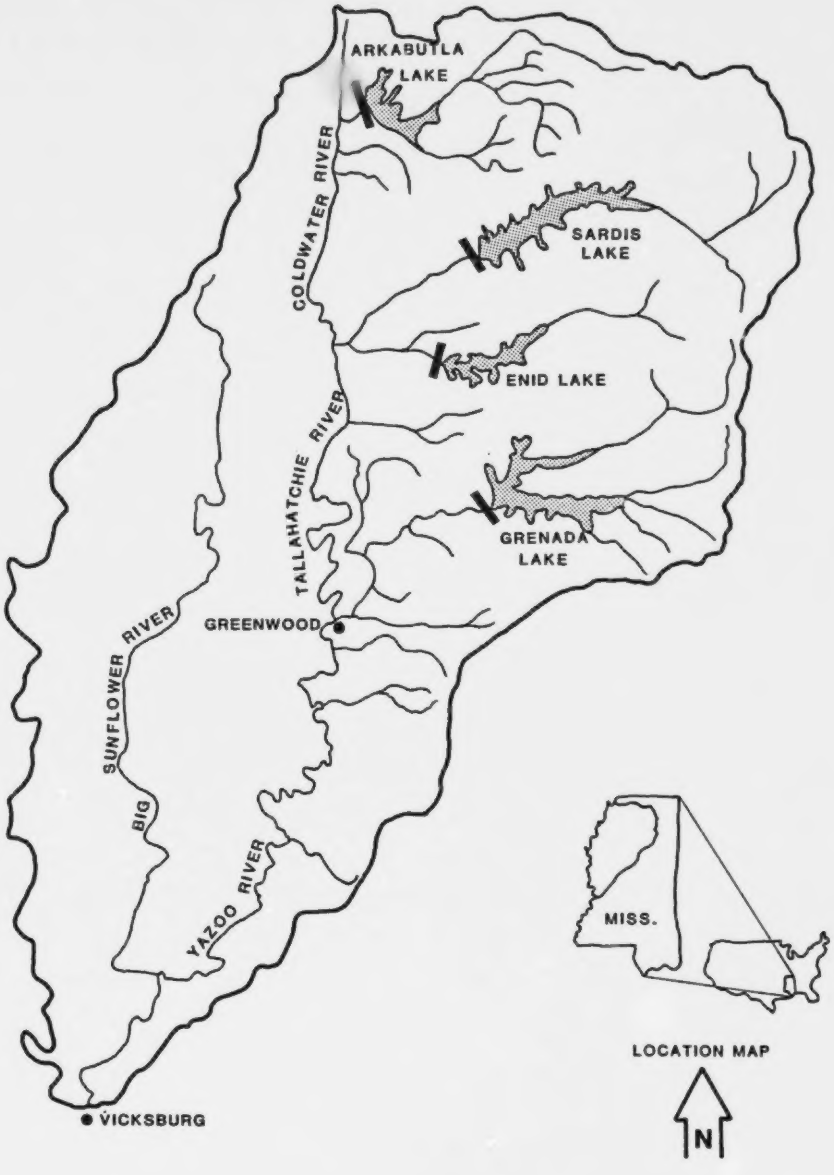

ARKABUTLA LAKE
COLDWATER RIVER
SARDIS LAKE
ENID LAKE
TALLAHATCHIE RIVER
GRENADA LAKE
GREENWOOD
SUNFLOWER RIVER
BIG
YAZOO RIVER
VICKSBURG
MISS.
LOCATION MAP
N

Figure 2.1 Yazoo Basin location map.

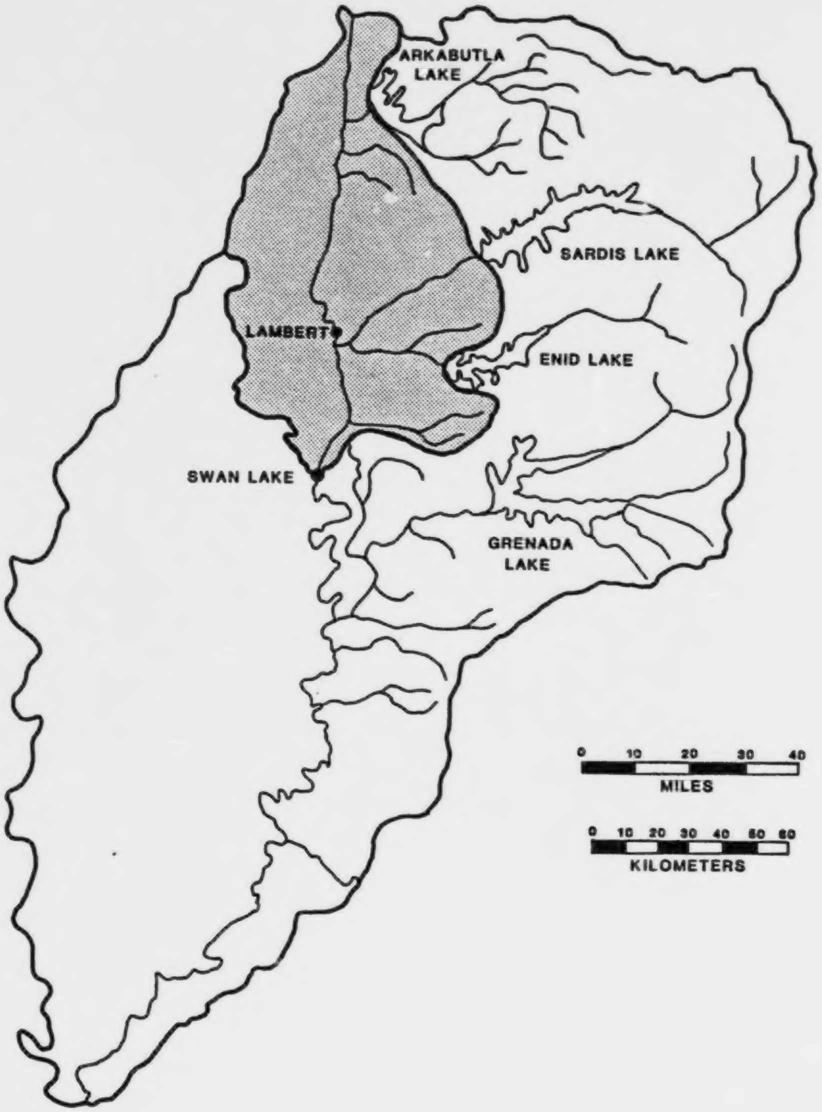

ARKABUTLA LAKE
SARDIS LAKE
LAMBERT
ENID LAKE
SWAN LAKE
GRENADA LAKE
0 10 20 30 40
MILES
0 10 20 30 40 50 60
KILOMETERS

Figure 2.2 Study area location map.

5477 sq. km (2115 sq. mi.) and a major river channel 142 km (88.4 mi.) long. The Coldwater-Tallahatchie River system flows through the study area and accepts water from the land immediately surrounding the channel, as well as from a series of reservoirs located on the eastern border of the study area. These large reservoirs contain water draining from the rolling hills located within the Yazoo River Basin to the east. Table 2.1 shows factors determining the study area size related to the physical setting.

The Yazoo Basin is divided into two physiographically distinct regions; the delta flatlands to the west and the bluff area to the east. Delta land covers approximately twice as much area as the bluffs in the study basin. The delta flatland lies in the floodplain of the Mississippi River. The Mississippi River is controlled by a levee system, effectively blocking surface water exchange with the Yazoo Basin. The eastern portion of the study area is comprised of bluffs rising over the delta developing into rolling hills that extend to the east. Three reservoirs located above the bluff line, that drain the eastern hills, provide a major input to the main channel of the Yazoo River system flowing through the delta.

The bluff region covers 1750 sq. km (676 sq. mi.) or 32% of the study area. It ranges from 24-40 km (15-25 mi.) in width and is approximately 121 km (75 mi.) long. Elevations range from 131 m (430 ft) above MSL in the south bluffs to 61 m (200 ft) along the bluff-delta line. The bluffs are not so precipitous in the north, their high elevation averaging about 91 m (300 ft) above MSL. Slopes range from 0 to >45%. Gently sloping ridgetops are broad and straight. Long and narrow drains form valleys that have level to gently sloping bottomlands. The hillsides separating ridgetops and valleys are generally steep and forested.

TABLE 2.1 FACTORS DETERMINING THE SIZE OF THE STUDY AREA

Factors	Area (Sq. km)	Percent
Yazoo River Basin	34,387	100%
Controlled by Reservoirs	11,461	33%
Below most Downstream Gage @ Greenwood	15,092	44%
Land between Swan Lake & Greenwood	2,357	7%
Total Area for Simulation	5,478	16%

Stream valleys are narrow in the upper reaches and broaden to wide, flat floodplains as they leave the bluffs. A large amount of sand is deposited by streams as they enter the delta region, resulting in dynamic channel cross-sections that change with each major storm (Waylon Hill, COE, personal communication, 4/83). There are many small flood detention reservoirs located throughout the bluff region. These reservoirs control between 10-70% of each small water basin emptying onto the delta flatlands (SCS, personal communication, 4/83). Below these small upland reservoirs, various amounts of channel improvements have been built to mitigate potential flood damages.

The delta region covers 3725 sq. km (1439 sq. mi.) or 68% of the study area. Elevations range from 61 m (200 ft) above MSL along the bluff line to 33 m (108 ft) at the most downstream point, the Swan Lake streamgage. The delta area was formed by a very large ice age river, created by retreating glaciers. The present day Mississippi River is much smaller and so occupies a very limited portion of the ancient river channel (USDA, 1976). Until construction of the levee system that borders the Mississippi River, frequent flooding occurred across the level to gently undulating surrounding lands. The Coldwater-Tallahatchie River system flows over these lands, through the original Mississippi River flood plain, and drops an average of only .095 m/km (.5 ft/mi.) along its 142.2 km (88.4 mi.) flow path. The Coldwater and Tallahatchie Rivers have deposited sediment through the course of their development, raising the channel above much of the surrounding landscape. Many oxbow lakes remain as remnants of historic channel courseways.

Intermittent flooding over time has developed the delta region into productive farmland. Flood control structures and channelization projects have reduced the flood hazard potential substantially over the past 100 years. Extensive work by the U.S. Army Corps of Engineers has resulted in some form of channel improvement along the total length of the Coldwater-Tallahatchie River system, including most of the major tributaries (USDA, 1975). Channel maintenance and proper reservoir management should result in a stable system for future agricultural development.

2.2 CLIMATE

The climate of the Yazoo River Basin is humid and sub-tropical. Summers are hot and sultry, winters are wet and moderate. In the spring and summer months the wind blows from the south or southwest providing warm moist air from the Gulf of Mexico. During the winter, winds blow from the north and northwest bringing cool temperatures from the continent.

The average annual air temperature ranges between 16.9 and 18.1 deg. C (62.4-64.5 deg. F) from north to south. Average monthly extremes occur in July at between 27.0 and 27.8 deg. C (80.6-82.1 deg. F) and in January between 6.3 and 7.9 deg. C (43.4-46.3 deg. F). Freezing temperatures may occur during the winter months for periods lasting a few days. The average length of the growing season is 220 days with the average date of the last killing frost on April 25 and the first in the fall on October 11.

Although rainfall is well distributed throughout the year, pronounced local variations may occur due to summer thunderstorm activity. During the winter, most storms are frontal systems that result from cold air moving down from the north and moist air moving up from the south. The average annual rainfall for the entire study area is close to 132 cm

(52 in.). The greatest amount of rainfall occurs between December and April. The driest period of the year is September through October. The most intense rainfall in terms of inches per hour occurs during local summer thunderstorm activity and can result in severe flooding (USDA, 1975). Average annual pan evaporation ranges between 140 and 152 cm (55-60 in.) annually. Monthly averages range from about 5 cm (2 in.) in January and December, to 20 cm (8 in.) in June and July.

2.3 SOILS, GEOLOGY, AND EROSION

The two physiographically distinct regions of the Yazoo Basin were formed as the result of a large ancestral river to the Mississippi, as previously described. The glacial river deposited rock flour and other finely ground rock along its borders as it flowed to the Gulf of Mexico (Galberry, 1963). After the river receded, wind blew the fine alluvial material (loess) into the hills to the east. The geologic map and a brief description of the geologic units are included in Figure 2.3 and Table 2.2. The delta is completely covered by alluvium. The bluff area is composed of three different tertiary formations and capped with various depths of loess.

Until the late 1800's, when levees were built, flooding of the Mississippi River spread soils from a wide expanse of northern states across the delta area. Much of this northern area is covered by glacial deposits of fairly recent geologic age. Relatively unweathered minerals have been carried by the river from these regions. Tributaries of the Mississippi River that extend into the Appalachian Mountains and Cumberland Plateau carry old and highly weathered minerals. Sediments originating from the wide range of northern sources resulted

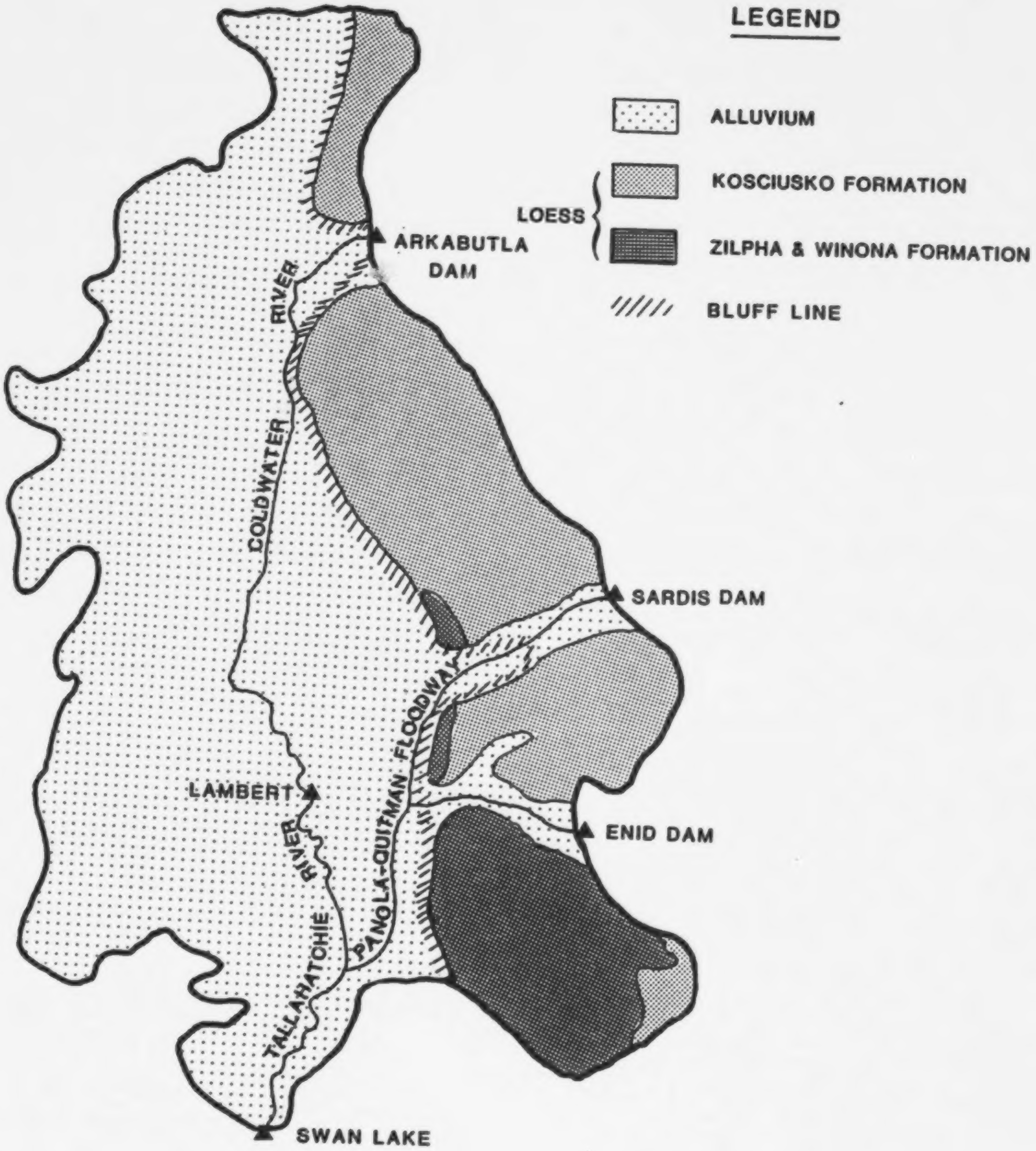

LEGEND
ALLUVIUM
LOESS
KOSCIUSKO FORMATION
ZILPHA & WINONA FORMATION
BLUFF LINE
ARKABUTLA DAM
COLDWATER RIVER
SARDIS DAM
PANOLA-QUITMAN FLOODWAY
LAMBERT
ENID DAM
TALLAHATCHIE RIVER
SWAN LAKE

Figure 2.3 Geologic map of the study area.

TABLE 2.2 GEOLOGIC UNITS OF THE STUDY AREA (Source: Simons and Li, 1983)

	Period (Epoch)	Group	Formation	Description
Delta	Quaternary (Holocene)	-	Alluvium	Loam, sand, gravel, and clay
Bluff	Quaternary	-	Loess	Grayish to yellowish-brown massive silt
	Tertiary (Eocene)	Claiborne	Kosciusko	Irregularly bedded sand, clay, and some quartzite
			Zilpha	Clay, and some glauconitic sand
			Winona	Highly glauconitic clayey sand

in an equally wide range of minerals in the parent materials of the soils in the delta (Wynn, 1959). These parent materials are a mixture of tertiary sands, silts, and clays.

All land forms in the delta region are a result of sedimentary processes. The only topographic relief is provided by natural levees, swales, and sloughs. Sediments have been deposited by moving water at different flow rates, depending on their size. Sands are dropped close to channels as the water moves relatively fast. Silts and clays drop out as water speed decreases, further from the channel banks. High areas in the delta region, standing only a few feet above the norm, were generally formed by deposition of coarse materials. These natural levees maintain poor to moderate drainage capabilities depending on the age of their formation. On the low bottoms of the delta, sediments high in clay were deposited. These soils are poorly drained (Fowlks, 1956). About 66% of the soils in the delta have a severe to very severe wetness or flooding hazard. U.S. Dept. of Agriculture Soil Bulletins describe the soil as having moderate to high dispersion characteristics. As dispersion values increase, so increases the soil's susceptibility to erosion (Simons & Li, 1983). The delta alluvium reaches depths of 61 m (200 ft) in some places. Delta soils also consist of sediments carried by streams out of the bluff region to the east.

The bluff area soils, as mentioned above, were formed in loess and are silty. The mantle of the loess is approximately 9 m (30 ft) thick on the western boundary, thinning as it extends to the east. It is underlain by unconsolidated sands, silt, and clays, mainly of marine origin. Erosion has removed much of the loess from steeper slopes. Many of the bluff soils have a fragipan lying at depths of between 38 and 100 cm (15-40 in). Although channel stablization projects have been constructed, a fair amount of sediment is washed onto the delta at the foot of the bluffs every year. Approximately 60% of the area has soils with erosion hazards and 27% has some wetness or flooding problem.

The bluff and delta regions exhibit a wide range of erosion rates due to different slope characteristics. In both regions, the major source of erosion is cultivated cropland. Table 2.3 provides a breakdown of erosion sources for the study area. Cropland erosion provides, by far, the largest input of sediment to the system. The high level of streambank erosion keeps a large portion of the sediment in suspension. Throughout the delta, stream channel aggradation is slowly taking place. Some tributaries flowing out of the bluff region are degrading (Larry Banks, COE, personal communication, 7/84).

Streambank erosion in the bluff region is controlled by bed degradation. The streambeds are underlain by a poorly cemented iron sandstone, or "ironstone," that offers little stabilizing effect. As the cement breaks down and the ironstone crumbles, underlying layers 12-15 m (40-50 ft) deep of unconsolidated sands, silts, and clays are exposed. Many stream degradation problems can be traced to channel manipulation. Altering the natural flow through channelization and channel straightening has resulted in moving headcuts and subsequent bank erosion (Rentschler et al., 1979).

Streambed aggradation occurs in the main channel of the delta region, due primarily to the large sediment loads provided by cropland erosion. Cropland erosion rates vary dramatically with the land slope. Sediment yields, or sediment delivered past the downstream boundary of a watershed, relate directly to channel slopes. The bluff region, with its relatively steep slopes, produces almost as much erosion as the delta

TABLE 2.3 EROSION SOURCES IN THE YAZOO BASIN STUDY AREA
(Source: USDA 1979, 1980, 1982)

Land Use	Area (Ha)	Gross Erosion (x 1000 Tonnes)	Erosion Rate (Tonnes/Ha)
Cropland	243,283	5,784.6	23.78
Pasture	98,153	344.5	3.51
Forest	206,359	248.6	1.20
Gully	1,950	563.6	289.0
Streambank	710 km	2,475.6	3,487 Tonnes/km

even though there is far less cropland. Potential sediment yield is much greater in the bluff region due to the relatively steep channels and channel degradation processes taking place. However, distributed throughout the bluff region are many farm ponds and flood prevention reservoirs that trap both water and sediment. In some cases up to 70% of a watershed may be controlled by these structures. Usually the land most prone to erosion lies in the alluvial plain below the reservoirs.

Sediment yields tend toward 50% of gross erosion in the bluffs (including streambank erosion), while only about 6% in the delta (USDA, 1982). Table 2.4 shows erosion rates differentiated by land use and location. The bluff and delta figures were calculated from erosion rates estimated by the SCS. The hill figures were estimated by Dendy et al. (1979) for a region lying a few kilometers east of the bluff line, where the land slopes are less severe.

Gully erosion is restricted to the bluff region and occurs primarily in crop and pasture lands. Although gully acreage is small, the total erosion impact nearly equals that of forest and pasture land combined (Table 2.3).

2.4 LAND USES AND MANAGEMENT

The Yazoo River Basin is located in [illegible] of the most intensively farmed areas of the United States. Approximately 44% of the study area is planted with crops, 18% is pasture, and 38% forested land. A very minor element is covered by urban land, wetlands, lakes, and roads. Table 2.5 presents a breakdown of land use coverage for various regions within the state of Mississippi.

TABLE 2.4 EROSION RATES ASSOCIATED WITH LAND USE AND PHYSIOGRAPHIC LOCATION (Source: USDA 1979, 1980, 1982, and Dendy et al., 1979)

	Erosion Rates (Tonnes/Ha)		
Location	Cropland	Pasture	Forest
Bluff	60.89	8.47	2.47
Hill	53.79	3.59	.18
Delta	16.02	.31	.13

TABLE 2.5 LAND USE BREAKDOWN (Source: USDA 1975, 1982)

	Percent Land Cover			
Location	Cropland	Pasture	Forest	Other
Bluff	24	22	54	-
Delta	54	16	30	-
Study Area	44	18	38	-
Yazoo Basin	39	20	35	6
Mississippi	22	14	55	9

2.4.1 Agricultural Crops

The major agricultural crops grown in the basin are soybeans and cotton. In 1970, 54% of the harvested acreage in the Yazoo Basin was devoted to soybeans. This is expected to increase 2-6% by the year 2000. Thirty percent of the harvested acreage was devoted to cotton in 1970. This should decrease to around 20% by the end of the century (USDA, 1975). The crops are grown uniformly throughout the delta region and cover approximately 54% of the land area. The bluff region offers limited flatland area available for cultivation. Most farming activities are located to the east where the hills are rolling. Cropland covers only about 25% of the bluff area.

2.4.1.1 Soybeans--

The amount of acreage devoted to soybeans has increased dramatically over the past 30 years. During the 1960's the harvested acreage of soybeans surpassed that of cotton. Soybeans are expected to dominate acreage for the foreseeable future (USDA, 1975).

In the past, soybeans were single-cropped: planted in May, harvested in October, and a residue left on the ground until the following spring when planting is repeated. Over the last 15 years double-cropping with winter wheat has increased approximately ten fold. Due to low wheat prices in the early 1980's, single-cropping with irrigation has become more lucrative and the trend toward double-cropping has halted (Jim Parkman, SCS, personal communication, 5/84). Table 2.6 shows a typical sequence of tillage operations for soybeans.

TABLE 2.6 TYPICAL TILLAGE PRACTICES FOR MAJOR CROPS IN THE YAZOO BASIN

Month	Soybeans	Cotton
Jan		
Feb		
		Tandem disk
Mar		
	Tandem disk	
Apr	Disk hipper	Disk hipper
May		DO-ALL, plant
	DO-ALL, disk, plant	Cultivate
Jun	Cultivate	Cultivate
Jul	Cultivate	Cultivate
Aug		
Sep		
Oct	Harvest (residue remains)	Harvest
Nov		
		Cut/shred stalks, chisel plow, disk
Dec		

2.4.1.2 Cotton--

The most important cash crop grown in the Yazoo Basin is cotton. Soybeans dominate in acreage, but projections indicate that cotton will remain first in market receipts through about 1990 (USDA, 1975). Although acreage has declined, increased yields per acre have more than compensated for the cropland loss.

Cotton has traditionally been single-cropped in the Yazoo Basin. Typically cotton is planted in April and picked in October. Table 2.7 shows a typical sequence of tillage operations for cotton.

2.4.1.3 Other Crops--

Other crops in the basin include wheat, rice, corn, silage, oats, vegetables, fruits, nuts, hay, potatoes, peanuts, and grain sorghum. Approximately 20% of the harvested acreage is devoted to these crops. These crops make up a substantial part of the agricultural effort in the Yazoo Basin, but no single crop management practice can be used to represent all of their needs. Therefore, they have not been included in the simulation process.

2.4.2 Forest

Approximately 38% of the study area is devoted to forest land. Within this area three major forest types prevail. In the delta an oak-gum-cypress association predominates. These trees are commonly found in the Mississippi Delta Alluvium and make up the bottomland hardwoods. They are also found along the floodplains of upland streams. Oak-hickory stands are located along the bluff-line in the loessal hills. These forests are made up of 50% or more hardwoods and less than 25% southern pines. A small area in the bluff region is covered by oak-pine forests that include between 25 to 50% southern pine. Throughout the study area, hardwoods predominate.

2.4.3 Pasture

Pasture land makes up approximately 18% of the study area. There are two basic types of pasture land-use employed in the Yazoo Basin. Summer pastures are made up of bermuda and bahia grasses. Winter pastures are planted in improved grasses; such as oats, wheat, ryegrass, and fescue. In 1970 approximately 50% could be classified as permanent pasture, 32% as pastured forests, and 18% as pastured cropland. Total pastured land area is expected to increase to meet demands of livestock production, although soybean farm expansion generally consumes land currently devoted to pasture.

2.4.4 Other Land Uses

Approximately 6.5% of the entire Yazoo Basin can be classified as urban, built up, or land devoted to farmsteads, roads, feed lots, levees, drainage ditches, fence and hedgerows, rural residences, investment tracts, and mineral lands. Rural idle land area is expected to diminish as agricultural practices become more efficient, while the urban and built up land is expected to increase by about the same amount (USDA, 1975).

2.5 WATER RESOURCES

Rainfall averages approximately 132 cm (52 in.) across the Yazoo Basin annually. This amounts to more than 14.2 million acre-feet per year falling above the Swan Lake streamgage. Average annual flow volumes at the Swan Lake gage are 5.5 million acre-feet or 38% of the annual rainfall. The rest of this water either enters ground-water storage or leaves the basin through evapotranspiration.

The main channel of the Coldwater-Tallahatchie River system is fed by three major tributaries flowing from large reservoirs in the bluff region. Two of the larger streams, flowing from Sardis and Enid Reservoirs, feed into the Panola-Quitman Floodway. This drainage channel routes a large portion of the bluff runoff to a point downstream from where it would naturally enter the Tallahatchie River. Most of the water falling on land between the reservoirs and the Coldwater-Tallahatchie River first enters one of these tributaries to be carried to the main channel.

Upland streams flow from the bluffs onto the delta. They are generally narrow, fast flowing, fairly shallow and have sandy bottoms. Most carry heavy bedloads of sand which results in shifting flow patterns and unstable banks. As these streams enter the delta, sand is deposited and the flow route is subsequently modified.

The delta streams are typically slow, meandering, and tree lined. Most of them have sand bottoms and their streambanks are considered stable. These streams contain many widened areas that are generally wooded and harbor many forms of wildlife. Most of the available timber in the delta grows along these streams and lakes. Generally, delta streams have turbidity problems due to suspended silt occurring year-round.

2.5.1 Water Supply

The majority of surface streamflow originates in the tributaries located in the hills east of the bluff area. These tributaries drain 60% of the Yazoo Basin above Swan Lake into the four major reservoirs along the northern and eastern boundaries of the study area. Releases from the reservoirs greatly impact flows at the downstream gages. In 1970 water withdrawals from surface water comprised 55% of the total basin needs, while 45% were extracted from the ground. The major withdrawals of water were used for power generation and irrigation. Approximately 44% of all water withdrawn was consumed, the vast majority of which (58%) was used for irrigation. Essentially all water for municipal supply was extracted from ground-water sources.

2.5.2 Water Quality

Surface water quality is good for most uses. At low flows the dissolved solids content may become high due to ground-water discharge from underlying strata.

2.5.3 Irrigation Water

Other than for rice and some truck crops, irrigation is not essential for crop production in the Yazoo Basin. Most of the crops can be grown successfully without irrigation, although irrigation systems may be developed as insurance against drought periods.

Approximately 68,798 hectares, or 5% of the harvested acreage, are currently irrigated. Most of this irrigation takes place in the delta region where an estimated 40% of the water is supplied from ground water and 60% is supplied from surface water sources. Rice and cotton each cover about a third of the irrigated acreage, with soybeans covering one-fifth. Rice, however, uses over 50% of the total water supplied.

SECTION 3

AVAILABILITY AND SELECTION OF TIME SERIES DATA

3.1 HSPF TIME SERIES DATA REQUIREMENTS

Hydrologic and sediment simulation with HSPF requires the following time series data:

1. precipitation
2. potential evaporation
3. streamflow (for comparison with simulated results)
4. water temperature
5. sediment (for comparison with simulated results)
6. air temperature
7. wind speed
8. solar radiation
9. dewpoint temperature

Of these, air temperature, wind speed, solar radiation, and dewpoint temperature are all used primarily in HSPF snowmelt calculations. Winters are usually short and moderate in the Yazoo River Basin. The average monthly temperature for January at Greenwood is 6.7 deg. C (44 deg. F). The normal daily minimum temperature for January is approximately 1.7

deg. C (35 deg. F) within the region. For these reasons, snowmelt calculations were not performed in the Yazoo Basin simulations and only 5 time series were required:

1. precipitation
2. potential evaporation
3. streamflow
4. water temperature
5. sediment

3.2 AVAILABLE DATA

Within the Yazoo River Basin the National Weather Service maintains numerous hydrometeorologic data collection stations that have been in operation for over ten years. The U.S. Geological Survey also maintains recording streamflow gages at three points along the main stem of the greater Yazoo River as well as on numerous tributaries. All of the above stations are located on the map in Figure 3.1. The USGS streamflow stations located along the main stem of the Yazoo River system are listed in Table 3.1. The precipitation and evaporation stations are listed in Tables 3.2 and 3.3.

Data records were collected from all stations for the period 1971-1979. From these nine years, both calibration and verification periods were chosen. The calibration period was determined by locating three continuous years displaying a wide range of annual precipitation values. Available sediment data required that both calibration and verification periods cover the years 1973-1976.

Meeting these criteria resulted in the choice of 1975-1977 for calibration and 1971-1974 for verification. The calibration

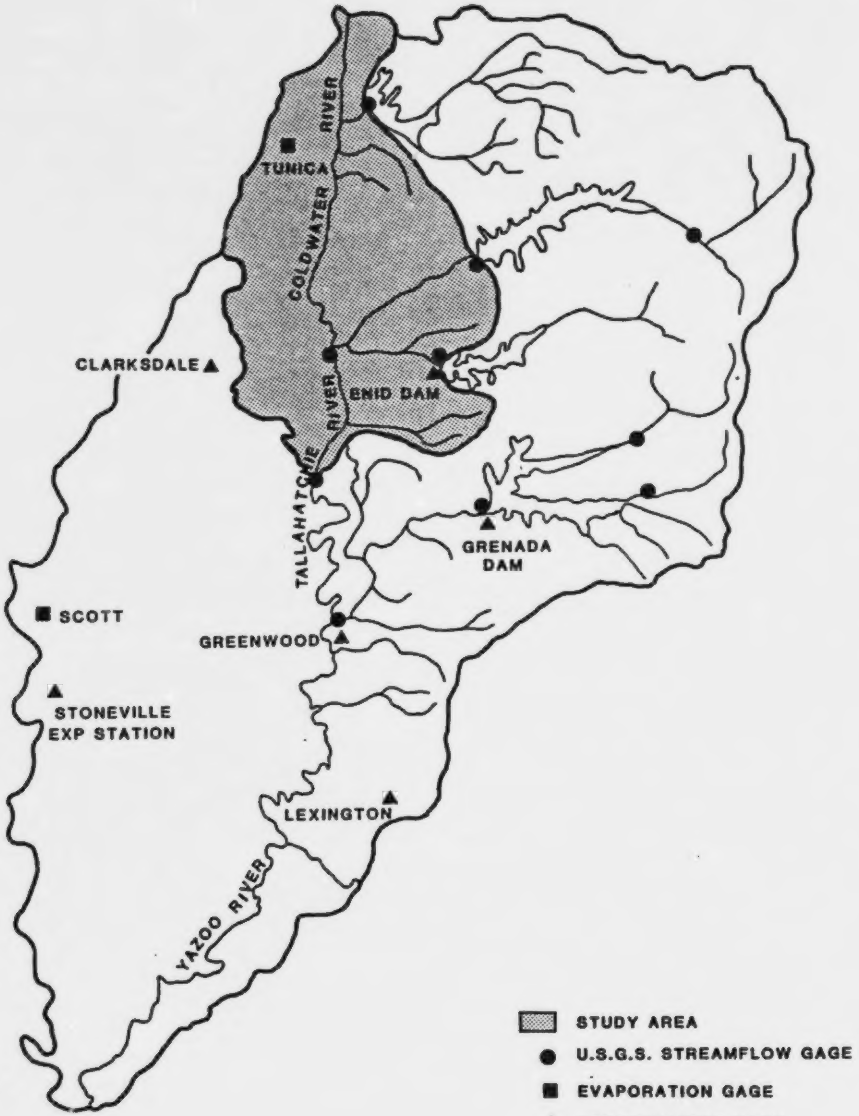

COLDWATER RIVER
TUNICA
CLARKSDALE
RIVER
ENID DAM
TALLAHATCHIE
GRENADA DAM
SCOTT
GREENWOOD
STONEVILLE EXP STATION
LEXINGTON
YAZOO RIVER
▨ STUDY AREA
● U.S.G.S. STREAMFLOW GAGE
■ EVAPORATION GAGE
▲ PRECIPITATION GAGE

Figure 3.1 Locations of precipitation, evaporation, and streamflow gages in the Yazoo Basin.

TABLE 3.1 USGS STREAM GAGES ON THE MAIN STEM OF THE YAZOO RIVER BASIN

Station No.	Location	Drainage Area (sq. km)	Period of Record Available for Simulation
07272500	Little Tallahatchie River at Sardis Dam	4,002	1/1971 - 12/1979
07275000	Yocona River at Enid Dam	1,450	1/1971 - 12/1979
07278500	Coldwater River at Arkabutla Dam	2,590	1/1971 - 09/1979
07280000	Tallahatchie River near Lambert	5,128	1/1971 - 09/1979
07281000	Tallahatchie River at Swan Lake	13,287	1/1971 - 12/1979
07285000	Yalobusha River at Grenada Dam	3,419	1/1971 - 12/1979
07287000	Yazoo River at Greenwood	19,296	1/1971 - 12/1979

TABLE 3.2 RECORDING HOURLY PRECIPITATION STATIONS IN THE YAZOO BASIN
(Source: Simons & Li, 1983)

Station No.	Station Name	Drainage Basin	Latitude N	Longitude W	Elevation (m)	Period of Record Available for Simulation
1707	Clarksdale	Yazoo Basin	34°12′	90°34′	54	1/1/71 - 12/31/79
2773	Enid Dam	Yazoo Basin	34°09′	89°55′	91	1/1/71 - 12/31/79
3619	Greenwood 2	Yazoo Basin	33°31′	90°11′	41	1/1/71 - 12/31/79
3650	Grenada Dam	Yazoo Basin	33°48′	89°46′	86	1/1/71 - 12/31/79
5062	Lexington 2 NNW	Yazoo Basin	33°08′	90°04′	96	1/1/71 - 12/31/79
8445	Stoneville Exp Sta	Yazoo Basin	33°25′	90°55′	39	1/1/71 - 12/31/79

TABLE 3.3 RECORDING DAILY EVAPORATION STATIONS IN THE YAZOO BASIN
(Source: Simons & Li, 1983)

Station No.	Station Name	Drainage Basin	Latitude N	Longitude W	Elevation (m)	Period of Record Available for Simulation
7886	Scott*	Yazoo Basin	33°36′	91°05′	43	1971 - 1979
8998	Tunica	Mississippi	34°41′	90°23′	58	1971 - 1979

* Discontinued in 1978, Data after 1978 are filled in by using mean monthly values of records from 1971 to 1977.

period allows for a wet year, a dry year, and a normal year of precipitation relative to the regional long term average.

Within the Yazoo River Basin, a smaller study area was delineated. This process required conformity to a consistent size criteria impressed on all of the representative watersheds. Adequate representation of streamflow and meteorologic events was also considered. Figure 3.1 shows the study area chosen within the Yazoo Basin; it covers an area of 5477 sq. km (2115 sq. mi.). The large size was required due to the locations of meteorologic and streamflow stations within the basin.

The Yazoo study area was chosen to represent the processes of erosion and pesticide transport for the agricultural region defined by the lower Mississippi River Valley. A majority of the land contributing to runoff in the study area is located in the Mississippi Delta Region. Parts of the bluff region, overlooking the delta, had to be included to define streamflow and sediment boundary conditions. The time series data sets chosen to represent hydro-meteorologic phenomena in the study area are outlined below.

3.3 SELECTION OF DATA FOR MODELING

3.3.1 Precipitation

Two hourly recording precipitation gages were chosen to represent rainfall across the study area. One gage lies in the bluffs at Enid Dam. The other gage is located in the delta, just west of the study area boundary, at Clarksdale. Rainfall at Enid Dam was applied to the entire bluff region.

Rainfall at Clarksdale was applied to the entire delta region. The long term annual precipitation estimated for the entire study area is approximately 132 cm (52 in.). An isohyetal map for the region is shown in Figure 3.2. Examination of the long term precipitation record of the two gages revealed that both deviate from the regional long term average over the study area. During the simulation, rainfall at each gage was multiplied by a factor to normalize measured values to the long term average of the study area. Figure 3.3 shows the location and assumed areal contribution of both rain gages.

3.3.2 Pan Evaporation

Mean annual potential evapotranspiration for the Yazoo Basin can be derived from pan evaporation measurements. Stations at Tunica and Scott (Figure 3.1) are the only two evaporation stations in the Yazoo Basin with records long enough for calibration purposes (5-10 years). The data collected at Tunica contains discrepencies, making it questionable as a representative gage for the study basin. Therefore, data collected at Scott was used to estimate potential evapotranspiration for the entire study area.

The recording of evaporation data at Scott was discontinued in 1978. Data values for 1979 have been filled in by averaging the mean monthly values collected at the station over the previous 8 years (this will be used in the representative site application). Examination of pan evaporation and lake evaporation data indicate that 0.75 should be used as the pan coefficient for this region (Environmental Data Service, 1968).

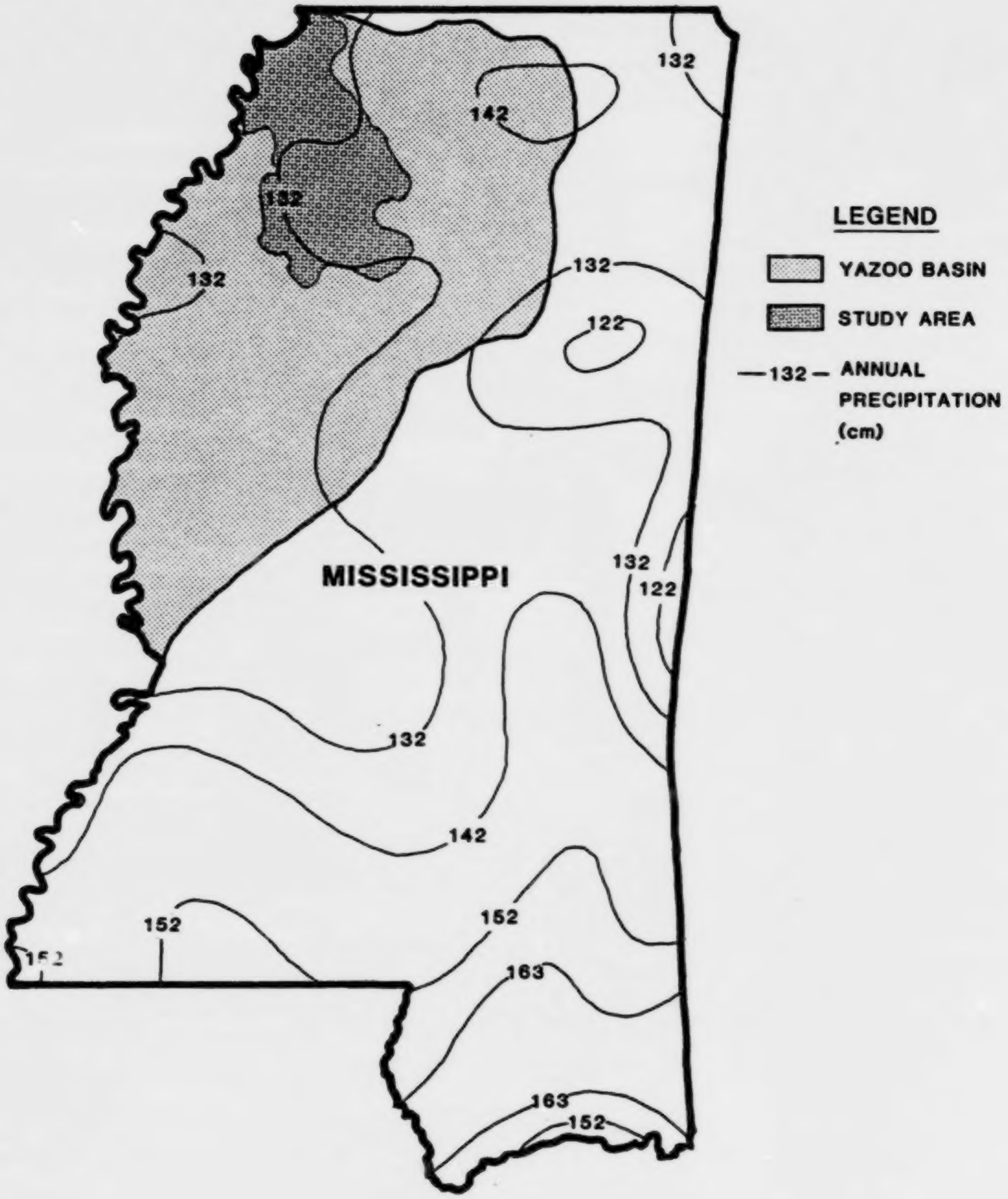

LEGEND
YAZOO BASIN
STUDY AREA
—132— ANNUAL PRECIPITATION (cm)
MISSISSIPPI
132
142
132
132
132
122
132
122
132
142
152
152
152
163
163
152

Figure 3.2 Mean annual precipitation in Mississippi (cm) (Source: Environmental Data Service, 1968).

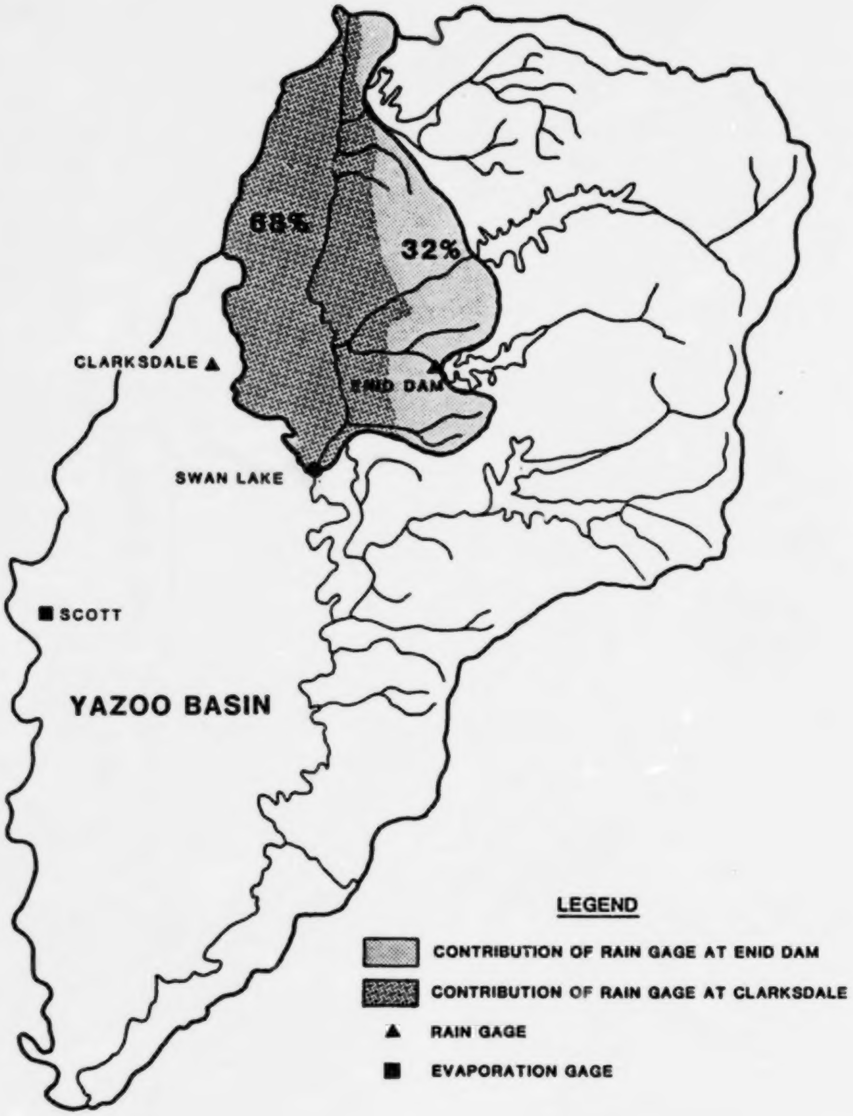

68%
32%
CLARKSDALE
ENID DAM
SWAN LAKE
SCOTT
YAZOO BASIN
LEGEND
CONTRIBUTION OF RAIN GAGE AT ENID DAM
CONTRIBUTION OF RAIN GAGE AT CLARKSDALE
RAIN GAGE
EVAPORATION GAGE

Figure 3.3 Assumed areal contribution of simulated raingages.

3.3.3 Streamflow

Two streamflow gages on the mainstem Yazoo River system above Swan Lake, as well as one on each of the three major tributaries, are operated by the U.S. Geological Survey. The gages along the main stem divide the river into two reaches; the upstream segment extending twice as long as the downstream one. The three gages on the main tributaries are located at the outlets of the large reservoirs along the study area boundary.

Water flowing from Arkabutla Reservoir provides the major headwater of the Yazoo River system. The other two reservoirs deliver water to the Panola-Quitman Floodway. This artificial drainage canal empties into the Tallahatchie River approximately one-half of the way between the stream gages at Lambert and Swan Lake. The western portion of the study area is ungaged. Water is delivered to the main stem through a series of bayous and drainage canals that meander extensively through the delta flatlands.

3.3.4 Water Temperature

Water temperature data has been gathered from one site on the Yazoo River, at Yazoo City. This data is used in the Toffaleti method employed by HSPF to simulate sand transport capability of the river.

3.3.5 Sediment

Sediment data have been collected at many sites throughout the Yazoo River Basin. Data collection activities have continued sporadically over the last 40 years. Sediment samples were collected during the period 1973-1976 at various points along the Coldwater-Tallahatchie River. Although the samples were collected at relatively even time intervals, not enough data exist to make detailed comparisons with simulated sediment concentrations. The data can be used as a general guide for calibration, but are insufficient to provide reliable storm peak and low flow sediment values needed for vigorous calibration and verification tests.

3.4 QUALITY OF SELECTED DATA

All of the time series data used in the Yazoo Basin simulation project had been previously collected by Simons and Li Associates of Fort Collins, CO for earlier studies. All missing precipitation data were replaced by values recorded at nearby stations. Over the three year calibration period, 27 days at Clarksdale and 16 days at Enid Dam were replaced. Missing evaporation data at Scott were replaced using the mean daily evaporation value of the month in question. Streamflows at Lambert and Swan Lake are partially regulated by upstream dams. Quality of records is not reported for these stations. It was noted during the calibration procedure that recorded flow rates at the dams were sometimes greater than at downstream gages over the same sets of days. These discrepancies were found during low-flow periods. Nothing was done to correct the problem because these cases were not critical to the simulation procedure. Water temperature data were collected at only one point in the Yazoo River, almost 150 km downstream of the study area. Average monthly values were used for the calculation of sand transport by the Toffaleti method. Although the streambed is slowly aggrading (Larry Banks, personal communication, 7/84), most of the transported sediment lies in the silt-clay size range and the movement of sand is of little importance to this study. Sediment data were recorded at a number of sites on the Yazoo River system, including many tributaries. Only those values measured at Lambert and Swan Lake were used for calibration purposes. The values were used as a guide to setting sediment runoff and transport parameters, but were insufficient in number to allow rigorous statistical analysis.

3.5 DATA TIME SERIES SUMMARY

Of the six hourly recording precipitation gages located in the Yazoo River Basin, two were chosen to represent rainfall onto the study area. The Clarksdale gage lies a couple of kilometers to the west of the study area and represents the delta region. The Enid Dam gage lies on the south-eastern boundary of the study area and represents the bluff region. Because of discrepancies in the recorded evaporation data at Tunica, recorded evaporation at Scott was chosen to represent the entire study area. Scott lies in the delta region, approximately 75 km southwest of the Swan Lake stream gage. Streamflow is measured at three points along the Yazoo mainstem, as well as at all the dams supplying water to the major tributaries. The two upper mainstem gages were chosen, Lambert and Swan Lake, for calibration and verification. The outflows from Arkabutla Lake, Sardis Lake, and Enid Lake were treated as study boundary inflows. In this way, all major sources of water to the system were gaged. Use of the reservoirs as the eastern boundary insured that all suspended sediment measured at downstream sites was known to originate within the study area.

SECTION 4

WATERSHED SEGMENTATION FOR HSPF APPLICATION

4.1 PERVIOUS LAND SEGMENTATION

The segmentation of the watershed into pervious land segments (PLS's) for simulation by HSPF is based on evaluation of the following factors:

1. meteorologic patterns
2. soils characteristics
3. land use/cropping practices

4.1.1 Meteorologic Patterns

Although the bluffs rise abruptly over the delta, the elevation gain does not cause a detectable orographic effect on the regional climate. Examination of long term average annual precipitation recorded at gages in the bluffs and delta fails to show a difference in rainfall patterns. The two rainfall gages chosen to represent the study area exhibit a wide range of average annual values for the seven year study

TABLE 4.1 PRECIPITATION AT REPRESENTATIVE STATIONS (cm)

Station	1971	1972	1973	1974	1975	1976	1977	7-Yr. Avg.	Long-term Avg.	Regional Avg.
Clarksdale	116	161	184	181	180	108	137	152	127	132
Enid Dam	104	141	184	180	140	89	125	138	128	132

period. They are summarized in Table 4.1. Variability in rainfall between gages from year to year is most likely due to localized thunderstorm activity. Large variations have been noted between many rain gages throughout the region during this study.

Without an apparent meteorologic basis to segment the study area according to weather patterns, rainfall for the entire basin was represented by an areal weighting of both contributing gages. All land segments in the bluff region receive rainfall from Enid Dam. All land segments in the delta receive rainfall from Clarksdale.

4.1.2 Soils Characteristics

Soils have a large influence on basin discharge behavior because their properties determine the rates of infiltration, percolation, and interflow, which in turn affect the timing of surface runoff. Variability of soils characteristics within a watershed can produce different hydrologic responses from different parts of the basin. Individual PLS's were established to represent these different characteristics.

The two different physiographic regions of the study area provide for different rainfall-runoff responses. Most of this is due to the lack of land slope in the delta and the relatively steep slopes of the bluff region. The movement of water over the land surface and in channels has a much more pronounced effect in the bluffs, where erosion occurs more readily than in the delta.

The bluff area consists of two major soil groups, distinguished by their drainage properties and geographic locations. The moderately sloping to very steep upland areas are covered with well-drained silty soils that formed in loess and have a medium textured or moderately fine textured sub-soil. Slopes range from 5-30%. The lowland areas are comprised of moderately well-drained to poorly drained soils that are medium textured throughout. They are nearly level and formed in silty alluvium on flood plains and in upland drainage ways.

The delta area consists of soil groups that offer a wide range of drainage characteristics. The history of deposition and subsequent weathering distinguishes each soil type in terms of its suitability for agricultural development. Soils range from excessively drained to very poorly drained. The clays deposited in depressed areas can be tilled only within a restricted range of soil moisture conditions. They often require artificial drainage. Only a very small percentage of soils are well drained. These occur mostly as old natural levees where stratified layers of fine-, medium-, and sometimes coarse-textured alluvium have been deposited. Along the bluff line, recent sediments washed down from the loess covered uplands result in a narrow band of fine to medium textured, somewhat poorly drained to moderately well drained silty soils. These areas are still occasionally flooded from streams flowing out of the bluffs.

Both the bluff and delta regions are composed of soils with a wide range of runoff characteristics. These soils are distributed uniformly throughout both areas and so effectively combine to produce a uniform response. No sub-areas can be uniquely defined by a single soil characteristic. However, the two physiographically distinct regions do provide different rainfall-runoff responses due to land slope and slope length characteristics. Land segmentation was performed in this manner, separating the bluff and delta.

4.1.3 Land Use

Land use affects the hydrologic response of a watershed by influencing infiltration, surface runoff, and water losses from evaporation or consumptive use by vegetation. The movement of water through the system, and subsequent erosion loss, is affected entirely through management of vegetation; be it crops, pasture, or forest. The Yazoo Basin is a region extensively devoted to agriculture, where lack of soils management has resulted in major erosion problems.

Cropland, pasture, and forest comprise the major land uses of the Yazoo Basin. The extent and management of each land type has been discussed earlier in Section 2.4. Following is a breakdown of the study area into component land segments based on these uses.

The majority of cropland is found in the delta region. Cropland acreage is dominated by soybeans and cotton. The management of land differs between the two major crops in terms of timing of tillage operations and the types of agricultural chemicals used to insure maximum crop production and ease of harvest. The two crops were chosen to delineate separate PLS's in the delta. It is here that different agricultural management practices will have the largest impact on erosion, and ultimately, pesticide movement through the system.

The bluff region is not as intensively cropped as the delta. Soybeans and cotton remain the top crops in terms of acreage, but a higher percentage of alternative crops are grown. Altering land management practices for individual crops will have a minor impact on the response of the entire Yazoo system. To maintain simplicity, the crops on the bluffs are treated as a single PLS.

The pasture of the bluffs and the delta are separated into different PLS's, but within these physiographically distinct regions no differentiation is made between pasture types and management practices. The same is true of forest land. As mentioned in Section 2.4, there are three major forest associations; one type predominates in the alluvial soils, the other two grow on hillsides of the bluff region. All three provide similar hydrologic and erosion responses and so are separated into two PLS's, reflecting the terrain of the delta flatlands and the sloping bluffs.

4.1.4 Final Pervious Land Segmentation

The Yazoo Basin study area has been divided into pervious land segments based primarily on land slopes and lengths, as well as major land use differences. The resulting seven PLS's are defined below with their attendant areal coverage in percent of total land area:

1. Bluff forest	17.3%
2. Bluff pasture	7.0%
3. Bluff crop	7.7%
4. Delta forest	20.4%
5. Delta pasture	10.9%
6. Delta soybeans	25.1%
7. Delta cotton	11.6%

4.2 IMPERVIOUS LAND SEGMENTATION

Only a minor portion of the study area is devoted to urban areas with associated impervious land. For this reason, the hydrologic response of these areas will have a negligible effect on the response of the whole system. No impervious land segments have been included in the modeling effort.

4.3 CHANNEL SEGMENTATION AND NETWORK

Stream reach segmentation requires consideration of river travel time, river-bed slope continuity, and entry points of major tributaries. The following sections describe the method and data used to accomplish this task.

4.3.1 Channel Characteristics

Channel length : 142.2 km
Channel slope : 0.095 m/km
Flow through time for mean flow : 45 hours
Velocity at mean flow : 0.9 m/s

The hydraulic routing algorithms in HSPF are most accurate when flow time through each reach approximates the simulation time step. A 2-hour time step was chosen for routing, which results in approximately 20 reaches for greatest simulation accuracy. Because the calibration was based on comparison of average daily flow and sediment values, and to accommodate computer run-time and cost constraints, the number of reaches was reduced and reach lengths were increased. The use of longer reaches tends to reduce and spread out instantaneous peak flows, with minimal impact on average daily values. Use of long reaches is common practice in modeling large watersheds.

Channel slope does not change noticeably throughout the entire length of the river. There are no abrupt changes in elevation or backwater pools. Reach boundaries could not be delineated by points of slope discontinuity.

With these factors in mind, stream reach segmentation was first performed by locating stream gages along the main channel. There are two gages, located at Lambert and Swan Lake. They divide the river into two reaches; the northern segment 87 km (54.3 mi.) long and the southern segment 55 km (34.1 mi.) long. To keep computer run-time to a minimum while providing adequate definition of the river system, these original reaches have each been divided into two shorter segments. The reach boundaries were chosen by selecting major drainage areas emptying into the channel. Because of channelization that has taken place throughout the Yazoo Basin, there are relatively few tributary entry points along the Coldwater-Tallahatchie river system. Stream reach segmentation was performed where natural drainage boundaries allowed. This resulted in one long reach with a large amount of contributing land area, due to the fact that bayou drainage patterns in the delta region are so ill-defined. The remaining three main-channel reaches are all of approximately equal length and travel time. One reach acts as a tributary draining both Enid and Sardis reservoirs, as well as a substantial portion of the bluff area. This reach was established to accommodate the reservoir inflow and to take into account the steeper terrain of the bluff region emptying onto the flat delta.

4.3.2 FTABLE Definition

The hydraulic characteristics of each reach must be specified in an FTABLE for use in the HSPF input sequence. FTABLEs specify values for surface area, reach volume, and discharge for a series of selected average depths of water in the reach; intermediate values are interpolated.

FTABLEs were produced by an auxiliary computer program requiring inputs of reach dimensions, and Manning's n values for both the channel and the floodplain (Table 4.2). Manning's n was changed over the course of calibration, within the bounds estimated by Simons and Li (1978), to adjust flow timing simulated at the two streamgages.

Channel dimensions for the 4 main-channel reaches were developed from U.S. Army Corps of Engineers cross-section data collected at nine points along the river. Detailed cross-section information for the Panola-Quitman Floodway allowed for excellent representation of the tributary reach.

4.3.3 Reach Network Summary

The resulting study plan employs a network of 5 reaches, 4 of which are connected in series. The other reach enters the main channel at the top of the most downstream reach. A map of the reaches appears in Figure 4.1. The dashed lines represent the boundaries of the contributing land areas draining into each channel segment. The FTABLEs corresponding to each reach used for simulation are shown in Table 4.3.

TABLE 4.2 REACH CHARACTERISTICS OF THE YAZOO BASIN STUDY AREA SIMULATION NETWORK

Reach	Length km (mi.)	Average Slope %	Bottom Width m (ft)	Bankfull Width m (ft)	Channel Height m (ft)	Flood-plain Slope %	Channel n	Flood-plain n
1	21.6 (13.4)	.020	48.8 (160)	91.4 (300)	4.6 (15)	.002	.042	.200
2	65.8 (40.9)	.013	61.0 (200)	107. (350)	6.1 (20)	.002	.042	.200
3	30.9 (19.2)	.010	73.2 (240)	114. (375)	7.6 (25)	.002	.042	.200
4	77.6 (48.2)	.020	39.6 (130)	67.1 (220)	5.2 (17)	.002	.042	.200
5	24.0 (14.9)	.008	76.2 (250)	122. (400)	7.6 (25)	.002	.042	.200

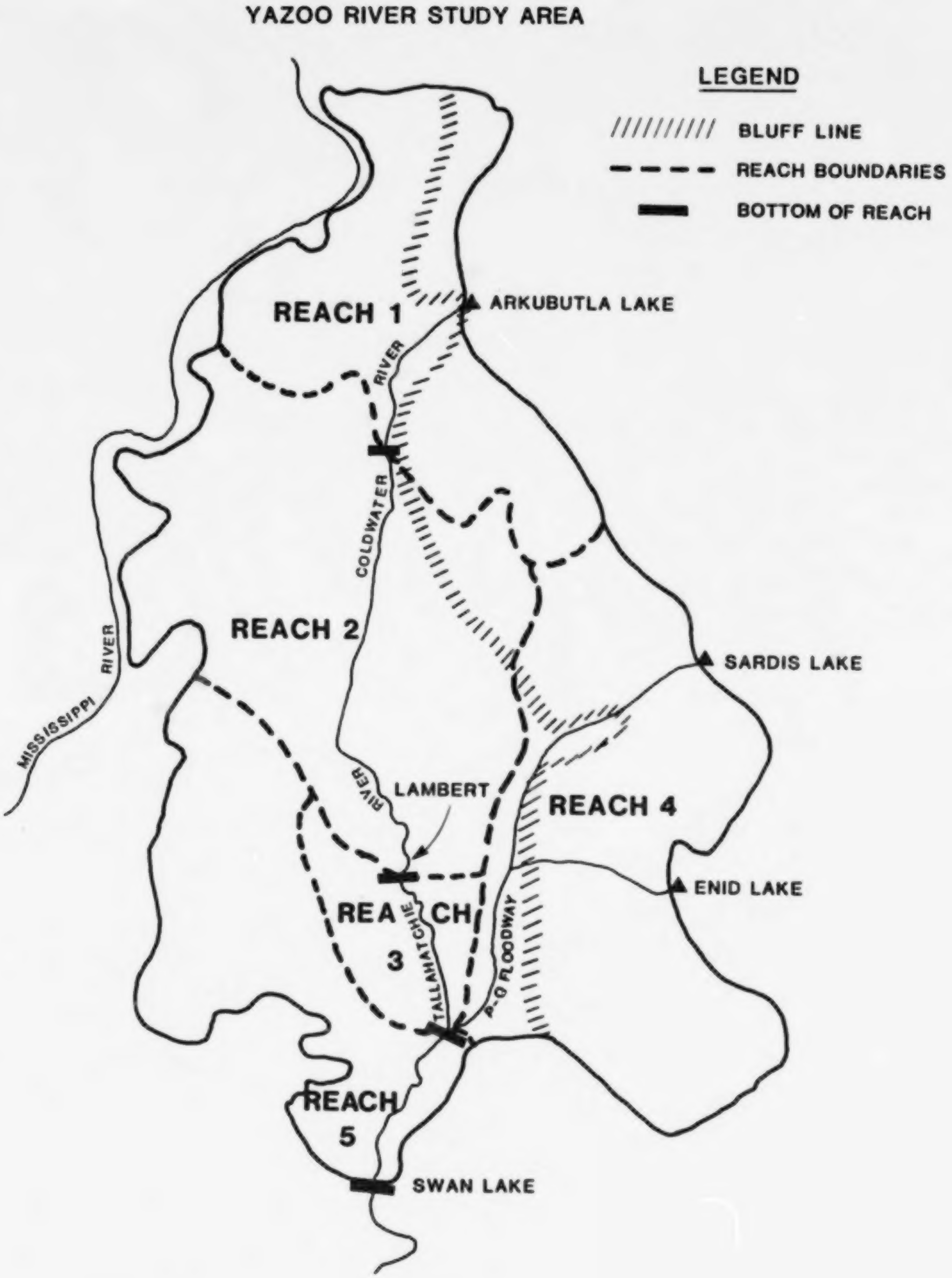

YAZOO RIVER STUDY AREA
LEGEND
////////// BLUFF LINE
- - - - REACH BOUNDARIES
▬ BOTTOM OF REACH
REACH 1
ARKUBUTLA LAKE
RIVER
COLDWATER
REACH 2
MISSISSIPPI RIVER
SARDIS LAKE
RIVER
LAMBERT
REACH 4
ENID LAKE
REACH 3
TALLAHATCHIE
A-O FLOODWAY
REACH 5
SWAN LAKE

Figure 4.1 Land area contributions to the reach network.

TABLE 4.3 FTABLES USED IN FINAL INPUT PARAMETER SET

```
FTABLES
  FTABLE       1
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.250   278.828  336.6919  117.1902    2085.8
     2.500   297.778  697.0708  374.9657    1342.5
     3.750   316.727 1081.1365  751.3188    1044.7
     5.000   335.677 1488.0889 1231.3228     877.9
     6.250   354.626 1920.3284 1813.0876     768.9
     7.500   373.576 2375.4546 2495.0522     691.2
    10.000   411.475 3356.7676 4159.2227     585.9
    12.500   449.374 4432.8291 6229.4346     516.6
    15.000   487.273 5603.6367 8717.3340     466.7
    20.000  8608.40428343.031018326.4920    1122.8
    25.000 16729.69591688.484040068.2890    1661.3
    30.000 24850.910195640.00080258.2340    1769.7
  END FTABLE  1

  FTABLE       2
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.667  1053.485 1704.1667  191.1220    6473.5
     3.333  1115.455 3511.6167  613.2749    4157.1
     5.000  1177.424 5422.3486 1219.1370    3229.0
     6.667  1239.394 7436.3633 1992.6826    2709.3
     8.333  1301.364 9553.6641 2926.2222    2370.3
    10.000  1363.33311774.2420 4015.9282    2128.5
    13.333  1487.27316525.2540 6658.5801    1801.8
    16.667  1611.21221689.3950 9920.9668    1587.2
    20.000  1735.15227266.668013814.0920    1433.0
    26.667 34785.672149002.75029116.7420    3715.3
    33.333 67836.187491075.56065195.4920    5468.5
    40.000100886.6601053485.00133096.750    5746.4
  END FTABLE  2

  FTABLE       3
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     2.083   584.727 1190.9092  289.1972    2989.7
     4.167   610.909 2436.3638  924.5521    1913.1
     6.250   637.091 3736.3643 1830.7607    1481.7
     8.333   663.273 5090.9092 2980.3066    1240.1
    10.417   689.455 6500.0010 4358.5000    1082.7
    12.500   715.636 7963.6377 5956.6836     970.6
    16.667   768.00011054.5450 9794.2480     819.4
    20.833   820.36414363.639014473.2730     720.5
    25.000   872.72717890.910019991.8630     649.7
    33.333 20266.676105971.80041958.1250    1833.6
    41.667 39660.625355669.00096173.0780    2684.9
    50.000 59054.570766982.370200166.280    2781.8
  END FTABLE  3

  FTABLE       4
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.417   803.333 1107.0178  117.5550    6836.8
     2.833   847.151 2276.1113  376.4614    4389.4
     4.250   890.970 3507.2803  746.9003    3409.1
     5.667   934.788 4800.5254 1218.4529    2860.3
     7.083   978.606 6155.8467 1785.8984    2502.5
     8.500  1022.424 7573.2412 2446.4399    2247.4
    11.333  1110.06110594.2620 4041.9678    1902.9
    14.167  1197.69713863.5900 6002.3105    1676.8
    17.000  1285.33317381.2110 8331.5840    1514.6
    22.667 34392.406110468.17018323.2380    4693.9
    28.333 67499.484407161.94044524.6640    6639.0
    34.000100606.550883462.25095884.6880    6689.2
  END FTABLE  4

  FTABLE       5
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     2.083   474.091  964.1730  265.1011    2640.5
     4.167   496.667 1975.3789  848.2485    1690.7
     6.250   519.242 3033.6182 1681.1653    1310.0
     8.333   541.818 4138.8896 2739.2739    1096.9
    10.417   564.394 5291.1943 4009.6968     958.0
    12.500   586.970 6490.5313 5485.0576     859.1
    16.667   632.121 9030.3027 9035.4395     725.6
    20.833   677.27311758.205013376.2090     638.2
    25.000   722.42414674.248018509.1870     575.6
    33.333 15772.93683404.922038682.0080    1565.4
    41.667 30823.445277556.56087417.8440    2305.1
    50.000 45873.953597129.120180111.690    2406.9
  END FTABLE  5

END FTABLES
```

4.4 CONNECTIVITY OF LAND SEGMENTS AND STREAM REACHES

Within the delta and bluff regions of the study area, land-use distributions are approximately uniform. Soybeans and cotton are grown wherever crops can be grown on a large-scale basis. The steeper areas of the bluffs are devoted singly to forests, but this land area is of relatively minor extent. Each reach, therefore, receives runoff from all the land-use areas reflecting the relative amount of delta and bluff acreage associated with the reach. Reaches 1, 2, and 4 all accept runoff from both bluff and delta lands. Reaches 3 and 5 receive runoff only from delta lands. The distribution of bluff and delta lands contributing to each reach is provided in Table 4.4.

TABLE 4.4 CONTRIBUTING LAND AREAS TO EACH REACH

		Contributing Areas sq. km (sq. mi.)					
PLS	Land Use	RCH 1	RCH 2	RCH 3	RCH 4	RCH 5	Total
1	Bluff Forest	256 (99)	60 (23)		629 (243)		945 (365)
2	Bluff Pasture	104 (40)	23 (9)		256 (99)		383 (148)
3	Bluff Crop	114 (44)	26 (10)		280 (108)		420 (162)
4	Delta Forest	155 (60)	492 (190)	109 (42)	127 (49)	233 (90)	1116 (431)
5	Delta Pasture	83 (32)	262 (101)	60 (23)	67 (26)	124 (48)	596 (230)
6	Delta Soybean	192 (74)	609 (235)	135 (52)	160 (61)	287 (111)	1383 (533)
7	Delta Cotton	88 (34)	280 (108)	62 (24)	73 (28)	132 (51)	635 (245)
	Total	995 (384)	1753 (677)	365 (141)	1590 (614)	774 (299)	5478 (2115)

SECTION 5

HSPF CALIBRATION AND VERIFICATION

5.1 OVERVIEW AND SPECIAL PROBLEMS

The calibration process is performed to adjust selected model parameters so that simulated and observed system outputs agree within some measure of acceptance. Normally this is accomplished in several stages. The logical order is to calibrate land segment hydrologic processes followed by stream hydraulics. Observed watershed outputs and changes in storage are compared whenever possible to observed values. Next, sediment washoff from the land surface, followed by instream sediment process calibration, is performed. After the system is calibrated, the simulation results are verified by applying the input parameter set to the same watershed for a different time period and comparing resulting simulated outputs to observed outputs.

The Yazoo Basin study area calibration was performed in the above manner and followed the general procedures discussed in the HSPF Application Guide (Donigian et al., 1984). The results of the hydrologic calibration were evaluated using three main methods: comparison of simulated and observed annual and monthly runoff volumes; comparison of simulated and observed flow frequency curves; and comparison of simulated and observed hydrographs. Following these comparisons several statistical tests, described below, were performed to further evaluate the calibration results. Likewise for the sediment calibration, several comparisons between simulated results and estimated or observed values were made to evaluate the simulation of sediment proceses. These included: simulated sediment washoff loads and gross erosion estimates for the various land use types; simulated and observed instream sediment concentrations at the outlet of the basin; simulated and observed frequency curves of the instream concentrations; and the simulated and observed stability of the channel (i.e., degradation or aggradation).

The initial selection of parameters for the Yazoo Basin simulation was based on the earlier calibration of two smaller watersheds within the same region. The first of these watersheds had previously been studied by the U.S. EPA to estimate toxaphene concentrations in the Yazoo River (Hydrocomp, 1979). The study focused on a 15.6 ha (38.5 ac.) test watershed, a part of McWilliams Farm, located approximately 18 km (11 mi.) northwest of Clarksdale, MS. This farm lies only a few kilometers west of the study area. The farm is representative of the delta portion of the watershed currently being studied.

The second small watershed was Middle Fork Tillatoba Creek, which lies in the bluffs at the southeast corner of the study area. Tillatoba Creek was calibrated as an earlier part of this study to gain an understanding of the hydrologic processes characteristic of the bluff region.

These early calibrations were used as guides in evaluating model input parameters for the entire study area. Values for soils and land-use related parameters were originally formulated from information taken from SCS County Soil Surveys, regional studies, and personal communication with local officials. Guidelines for initial hydrologic parameter values were provided by the Agricultural Runoff Management (ARM) Model User's Manual (Donigian and Davis, 1978). Crop information was provided by local SCS agronomists and field personnel in the Yazoo Basin area. Channel characteristics and sediment data were obtained from the Army Corps of Engineers at Vicksburg.

Three years were chosen for the calibration period; 1975-1977. The first year was an extremely wet year, the second a dry year, and the third was close to average in terms of annual rainfall volumes. These years were also chosen because sediment samples were collected from 1973-1976. This would allow some portion of the available sediment data to be used in both the calibration and verification processes.

Special problems associated with calibration of the Yazoo Basin involve two separate types of data inadequacies for simulation. The first is reflected in the small number of gages, both meteorologic and streamflow, that characterize the system. Although long term average rainfall and streamflow values can be matched, individual storm events (e.g., thunderstorms) may be entirely missed or applied to a much larger area than actually affected. Another problem associated with a sparse gage distribution is that only large scale basin responses can be adequately modeled. For example, the bluff area of the Yazoo Basin has many small flood detention reservoirs that both alter storm runoff timing as well as sediment delivery to major channels. Because the bluff area is ungaged as a whole, the hydrologic response must be estimated and incorporated into a basin-wide response through calibration at the basin level.

roughness, effective channel cross-section dimensions) are needed to better represent hydrograph shape.

As discussed in Section 4, hydrologic simulation of the 5475 sq. km Yazoo study area was performed by modeling two meteorologic segments; both represented by the same evaporation gage and each by individual precipitation gages. Both meteorologic segments were then divided into pervious land segments (PLS's) indicative of major land uses in the area; forest land, pasture land, land devoted to soybeans, and land devoted to cotton.

5.1.1 Meteorologic Data and Parameter Development

Examination of long term average precipitation records for the Yazoo Basin revealed that rainfall across the study area approaches 132 cm (52 in.) annually. There appear to be no orographic effects along the bluffs. Although long-term annual volumes of rainfall may be uniform for the entire study area, pronounced short-term local deviations do exist. Each gage records values close to the long term regional average, but may deviate slightly from that value. Because precipitation was the most important determinant of simulated runoff in the Yazoo calibration, it was essential to adjust the recorded gage pecipitation to equal the regional value experienced across the study area. This was accomplished by dividing the long-term regional average by the long-term station average and multiplying each rainfall event (i.e., the entire time series) by this factor:

The second inadequacy lies in the lack of available sediment data. To obtain a truly reliable sediment calibration, data collected on a daily basis during storm events of various magnitudes is required. A continuous sediment concentration record for the simulation period would best suit calibration and verification needs. Sediment samples were collected in the Yazoo River Basin at various locations over a 2 1/2 year period at approximately 2 week intervals. Unfortunately, good concentration-discharge correlations do not exist and extreme concentration values cannot be reliably estimated. Major storm events are the primary mechanisms for significant sediment erosion and transport in the Yazoo Basin. Without good data representation, the sediment simulation cannot be accurately calibrated and verified. Fortunately, enough sediment concentration data does exist to allow a preliminary calibration and verification of the most frequently encountered range of runoff events, which was suffficient for the purposes of this study.

5.2 HYDROLOGIC/HYDRAULIC CALIBRATION AND VERIFICATION

In the application of HSPF to the Yazoo Basin, runoff was simulated from three components; surface runoff from pervious areas, interflow from pervious areas, and ground-water flow. Historic streamflow records are not divided into these components. Consequently, the relative magnitude of contributions from each pathway was inferred from the examination of the hydrograph shape and timing for many events over several years of continuous simulation. Although hydrologic/hydraulic calibration primarily relies on adjustments to the soil hydrologic parameters, occasionally adjustments to the hydraulic parameters (e.g., channel

$$\text{Normalization Factor} = \frac{\text{Regional Long-Term Average Precipitation}}{\text{Station Long-Term Average Precipitation}}$$

Bluff Area = 1.0324 * Enid Dam Precipitation data
Delta Area = 1.0415 * Clarksdale Precipitation data

Evaporation records at Scott were not normalized in this same manner because a regional pan evaporation factor had already been developed (Environmental Data Service, 1968) and there was insufficient data to establish a significant difference between the gage and regional values.

5.2.2 Simulation Time Step

During the early calibration attempts both 1-hour and 2-hour time steps were run to evaluate the effect on surface runoff volumes. A visual inspection of displays and hydrographs indicated that little definition was lost by use of the 2-hour time step, while substantial computer run-time savings were realized. Also, the 2-hour time step was consistent with the simulation of the other watersheds in this study.

5.2.3 Hydrologic Calibration

Prior to calibration of the Yazoo Basin study area, two smaller watersheds were calibrated to better define the hydrologic parameters for the physiographically distinct regions under consideration. The input sequence developed for the McWilliams farm toxaphene study (Hydrocomp, 1979) was applied to the delta portion of the study area, and the input sequence developed for the Middle Fork of Tillatoba Creek was applied to the bluff region. Some changes were made to the McWilliams Farm input sequence to allow ground water a greater role as a hydrologic pathway through the basin; the McWilliams Farm test watershed was too small for the ground-water component to influence flow at the gage.

Early calibration attempts resulted in reasonable simulations of annual runoff volumes, but oversimulation of large storm events and steep storm recessions required further tempering. Subsequent investigation showed that a few major runoff events were triggered by thunderstorms passing a representative precipitation gage, and therefore, delivering rainfall to uncharacteristically large land areas. Final calibrations resolved these problems while providing acceptable water budgets for each land segment.

Table 5.1 provides yearly comparisons of recorded and observed runoff at two USGS streamflow gages in the study area, for both the calibration and verification periods. Runoff volumes for the calibration period were consistently high. Precipitation records show that during 1975 and 1977 a couple of large storm events were recorded at one or the other representative gage, resulting in oversimulation of runoff. When these unrecorded volumes were subtracted from the simulated annual volumes, the values in parentheses (Table 5.1) resulted. The calibrated annual runoff volumes then fell between +9% and -7% of recorded values. During the verification period annual runoff fell between +17% and -13%, except for Swan Lake in 1971. The following criteria was considered in determining the quality of simulation results: 10% very good, 15% good, and >15% fair.

Table 5.2 provides a breakdown of the water budget by flow

TABLE 5.1 SUMMARY OF SIMULATED AND OBSERVED RUNOFF VOLUMES (cm)

Calibration

	Lambert			Swan Lake		
Year	SIM	OBS	Difference as a % of OBS	SIM	OBS	Difference as a % of OBS
1975	78.7 (68.8)*	73.9	+6 (-7)	76.7 (68.3)*	72.6	+6 (-6)
1976	32.8	31.0	+6	32.5	34.8	-7
1977	39.9 (30.0)*	28.7	+39 (+5)	40.6 (32.5)*	29.7	+37 (+9)
Total	151.4 (131.6)*	133.6	+13 (-2)	149.8 (133.3)*	137.1	+9 (-3)

Verification

Year	SIM	OBS	Difference as a % of OBS	SIM	OBS	Difference as a % of OBS
1971	29.7	33.0	-10	30.5	41.7	-27
1972	39.4	45.2	-13	39.1	40.9	-4
1973	94.2	84.3	+12	98.8	84.8	+17
1974	84.6	83.8	+1	89.9	85.3	+5
Total	247.9	246.3	+1	258.3	252.7	+2

SIM = Simulated
OBS = Observed

* Numbers in parentheses indicate runoff volumes subtracting major simulated storm events not observed at the streamgage.

TABLE 5.2 TYPICAL ANNUAL WATER BALANCE (CALIBRATION AND VERIFICATION) FOR THE SEVEN SIMULATED PERVIOUS LAND SEGMENTS (cm)

Calibration - 1977

cm	PLS 1 Bluff Forest	PLS 2 Bluff Pasture	PLS 3 Bluff Crop	PLS 4 Delta Forest	PLS 5 Delta Pasture	PLS 6 Delta Soybean	PLS 7 Delta Cotton
Precipitation	129.2	129.2	129.2	142.6	142.6	142.6	142.6
Evapotranspiration	91.6	74.5	80.5	96.3	81.9	87.9	87.7
Runoff	23.1	47.6	43.5	29.8	41.8	44.5	42.2
Surface	1.8	5.6	8.0	1.7	5.8	6.8	4.5
Interflow	7.0	15.1	16.0	20.1	28.5	27.4	22.1
Ground water	14.3	26.9	19.5	8.0	7.5	10.3	15.6

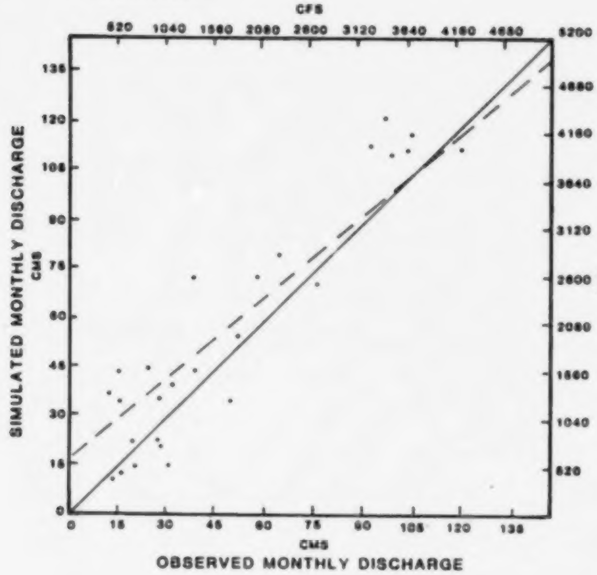
Verification - 1972

cm	PLS 1 Bluff Forest	PLS 2 Bluff Pasture	PLS 3 Bluff Crop	PLS 4 Delta Forest	PLS 5 Delta Pasture	PLS 6 Delta Soybean	PLS 7 Delta Cotton
Precipitation	145.8	145.8	145.8	167.9	167.9	167.9	167.9
Evapotranspiration	109.3	90.4	96.7	113.6	98.3	13.9	103.9
Runoff	17.8	43.1	40.9	25.0	50.3	48.2	45.8
Surface	0.3	1.6	3.2	0.9	3.0	6.5	5.8
Interflow	3.2	10.9	15.4	18.3	29.4	27.9	21.8
Ground water	14.3	30.6	22.3	5.8	17.9	13.8	18.2

components for representative calibration and verification years. Evapotranspiration (ET) in forest PLS's was maintained at a level close to potential. Crop ET was hand calculated by the Blaney-Criddle estimation procedure (Doorebos and Pruitt, 1977) and compared to simulated values on an annual basis. For the purposes of this study, partitioning between surface and sub-surface flow in the Delta region was the most important aspect of the simulation, since chemical transport to surface water bodies differs for each pathway (depending on component characteristics) and the Delta region is the major agricultural portion of the study area. The relative division of water between the sub-surface components, interflow and ground water, was determined through calibration of both the small watersheds and the larger study area.

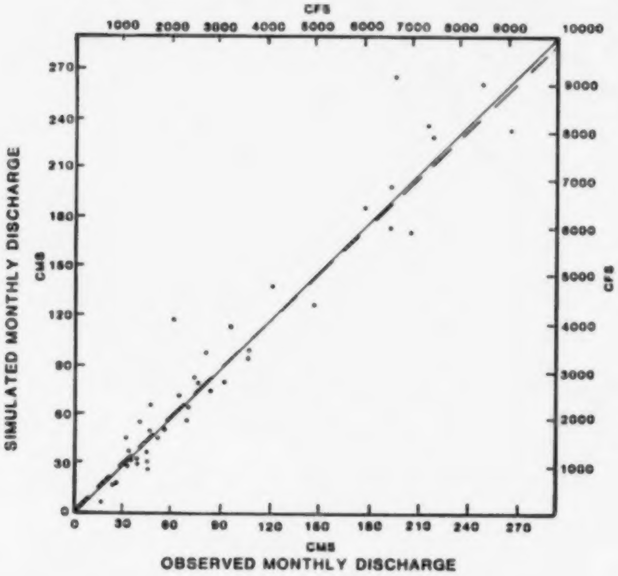
Figures 5.1 and 5.2 show correlation scattergrams for average monthly flow values at Lambert and Swan Lake during the calibration and verification periods. These scattergrams show that simulated monthly flows were generally close to observed flows. Flows were generally oversimulated at Lambert and at Swan Lake high-flow months were likewise oversimulated, while low-flow months were undersimulated. Inspection of simulated and observed monthly flow values at both gages did not indicate any discernable consistent intra-seasonal trends. In other words, although the scattergram for average monthly flow values at Swan Lake show a general undersimulation at low flows and oversimulation at high lows, contiguous months within any dry or wet season were not, as a whole, undersimulated or oversimulated. The verification plots indicate a better correlation between simulated and observed flows than for the calibrated period at both gages.

CALIBRATION



R^2 =.81
SLOPE =.84
Y-INTERCEPT=17.1 CMS

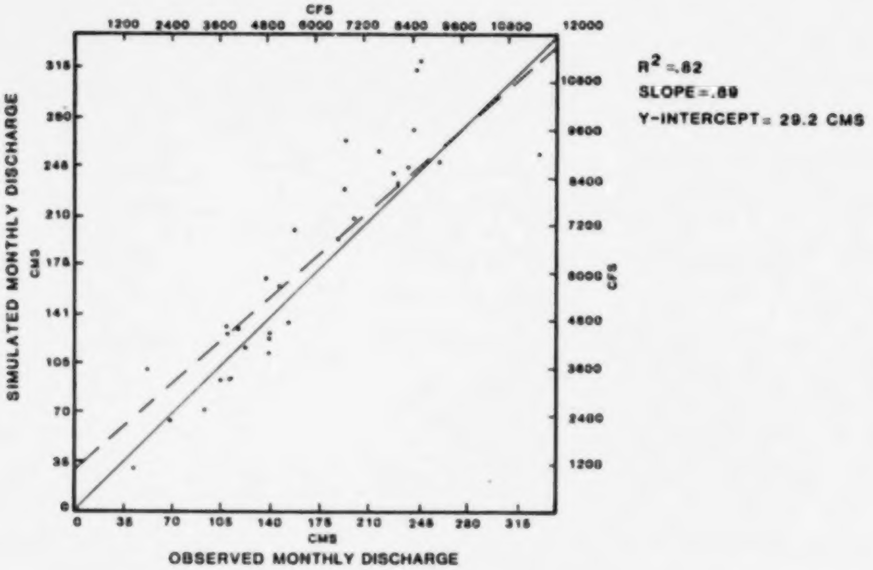
VERIFICATION



R^2 =.90
SLOPE=.97
Y-INTERCEPT= 3.1 CMS

Figure 5.1 Observed vs. simulated average monthly flow values at Lambert.

CALIBRATION



VERIFICATION

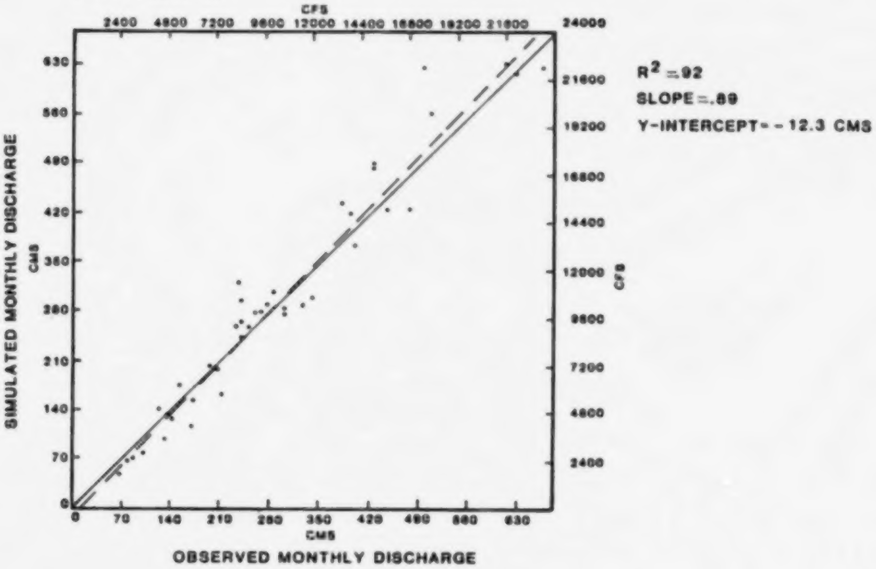


Figure 5.2 Observed vs. simulated average monthly flow values at Swan Lake.

5.2.4 Storm Hydrograph Simulation

Daily hydrographs provide a pictorial tool for making comparisons of streamflow timing and magnitude of both selected storms and seasonal trends. Figure 5.3 shows daily hydrographs, one year in length, for both calibration and verification periods. Both hydrographs include three traces; observed flow, simulated flow, and the reservoir contribution from Arkabutla Lake. In many cases, the reservoir component provides the majority of flow at the gage.

The calibration time series displays a number of interesting phenomena that are discussed below. In general, the simulated and observed flows match up well. At various points recorded data appear to be in error, affecting short-term response periods. Reservoir releases were regulated with the anticipation of storm events so that outflow was reduced during periods of rainfall, reducing the chance of downstream flooding. At the end of April this appears to happen, but no runoff peak was recorded. As a consequence of drastic reservoir release cutback, simulated flow was also substantially reduced. A look at the precipitation records of all the gages in the Yazoo Basin indicate that a rainfall event did begin on April 28 that lasted through April 30, 1975. Reservoir cutback began on April 26, a full two days before any rain had fallen. The fact that observed flow at Lambert remained essentially constant over this entire week indicates that gage records are suspect.

At the end of August, 1975 another streamgage discrepancy arises. During the period of August 28 - September 1 reservoir releases were substantially higher than recorded flows downstream at Lambert. Although a large diversion of water between the gages is possible, there is no indication of

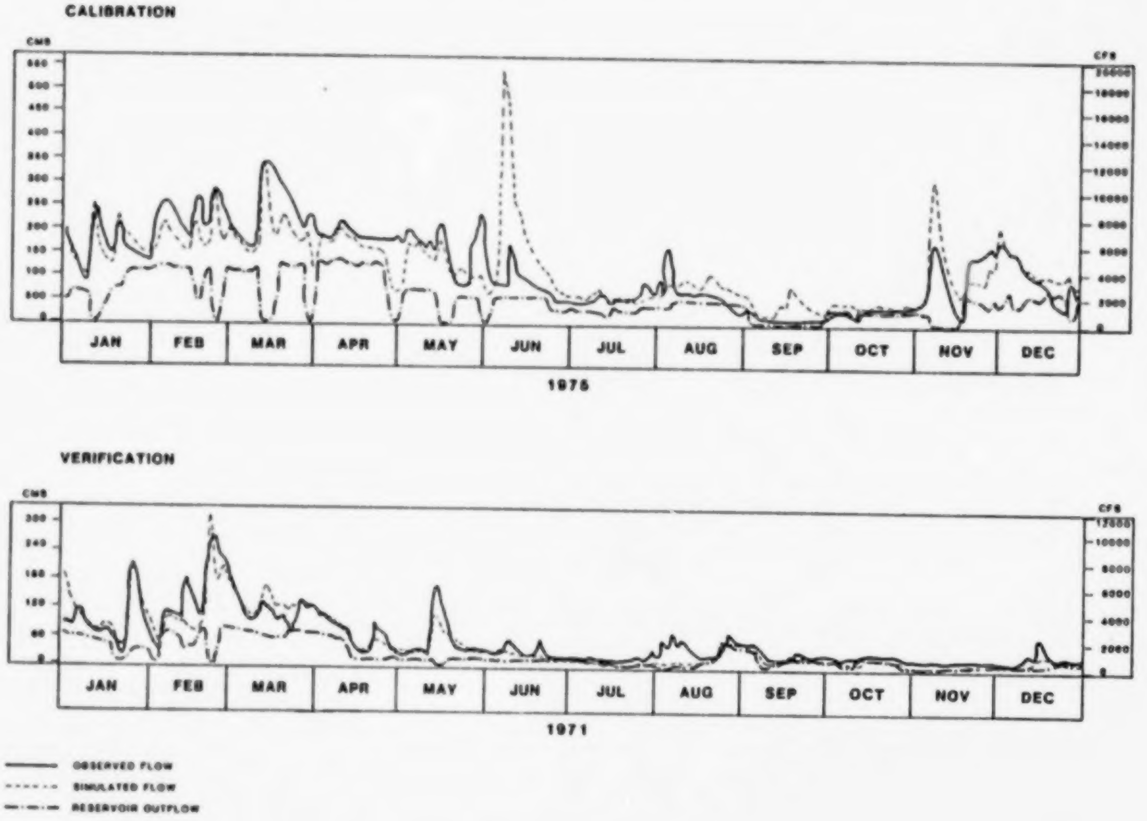


Figure 5.3 Daily hydrographs of flow at Lambert.

this in the historical data. This same situation arises a number of times throughout the simulation period during all seasons of the year.

The phenomenon of non-representative rainfall, which is a common problem for many rainfall-runoff simulations especially in the thunderstorm areas, occurred at the beginning of June, 1975. Here a storm was recorded at all gages on June 6. Clarksdale recorded 12.2 cm while the other gages recorded between .5 and 4.6 cm for the day. Reservoir release was not restricted and observed runoff at Lambert reflected a minor event. The simulated runoff responded strongly to recorded rainfall at Clarksdale, resulting in an additional 9.9 cm of water basin-wide not measured at the gages. This one simulated storm event produced unaccounted-for or oversimulated runoff amounting to over 13% of the total annual runoff of 1975. During the calibration procedure, this was taken into account and the oversimulated volume was not used when comparing annual runoff volumes. This type of simulation error can be reduced by including more rainfall gages, each contributing to smaller land areas. Major events such as the June 6th storm occurred during the calibration period once in 1975 and twice in 1977, to a lesser extent.

It is difficult to quantify the quality of day-to-day correlations between simulated and observed events. By plotting simulated vs. observed flow values on a scattergram and calculating the correlaton coefficient, observing the slope and y-intercept of the best-fit line, and looking for trends evidenced by bunched points, a relative measure of fit can be made. Table 5.3 provides R-squared, or coefficient of determination, values for mean daily, 3-day average, and mean monthly flows. An R-squared value greater than 0.80 generally indicates good to very good calibration results. The coefficient of determination for calibrated daily flows equals

TABLE 5.3 STATISTICS FROM REGRESSION ANALYSES OF STREAMFLOW (BEST-FIT LINE CALCULATED BY LEAST-SQUARES METHOD)

Calibration

	Lambert			Swan Lake		
	Slope	y-intercept	R^2	Slope	y-intercept	R^2
Mean Daily Flows	.79	733	.65	.88	1137	.69
3-Day Average Flows	.80	703	.67	.88	1136	.71
Mean Monthly Flows	.84	603	.81	.89	1030	.82

Verification

	Lambert			Swan Lake		
	Slope	y-intercept	R^2	Slope	y-intercept	R^2
Mean Daily Flows	.98	83	.81	1.05	-433	.85
3-Day Average Flows	.98	72	.84	1.06	-456	.86
Mean Monthly Flows	.97	111	.90	1.06	-435	.92

.65 and is of marginal quality, indicating that the daily match-up of simulated and calibrated values was not good. If R-squared had improved markedly by averaging the flows of three consecutive days, this would indicate that the simulated flows either lagged or preceded observed flows by a short increment of time. The fact that little improvement was seen in the 3-day average flow R-squared value indicates that there is no phase shift problem. The relatively low values derived from calibration, as compared to verification, are due in part to oversimulations resulting from the errant storm events of 1975 and 1977. If these events were eliminated from the calibration period, a best-fit line with characteristics closer to those of the verification test would emerge. Figures 5.1 and 5.2 illustrate graphically the statistics reported in Table 5.3 for the mean monthly flows. The good fit of simulated to observed values for the verification period helps to indicate that the calibration process was a success.

The daily hydrograph provides a continuous picture of simulated vs. observed runoff events, but may be difficult to interpret as a whole, stretching over multiple months or years. Flow frequency distributions, as displayed in Figures 5.4 and 5.5 provide a better indicator of the model's ability to represent watershed hydrologic response than exact simulation of individual events. This is especially true in areas subject to thunderstorms, as in the Yazoo Basin. Figures 5.4 and 5.5 show that for both the 3-year calibration period and the 4-year verification period, very good agreement of flow magnitudes resulted, especially for Swan Lake. For the purposes of this application of HSPF, a good matching of flow frequencies is of prime importance, as noted above. The curves at Lambert do not match as well as those at Swan Lake. A number of calibration runs were made to refine the simulated vs. observed divergences, but no significant improvements

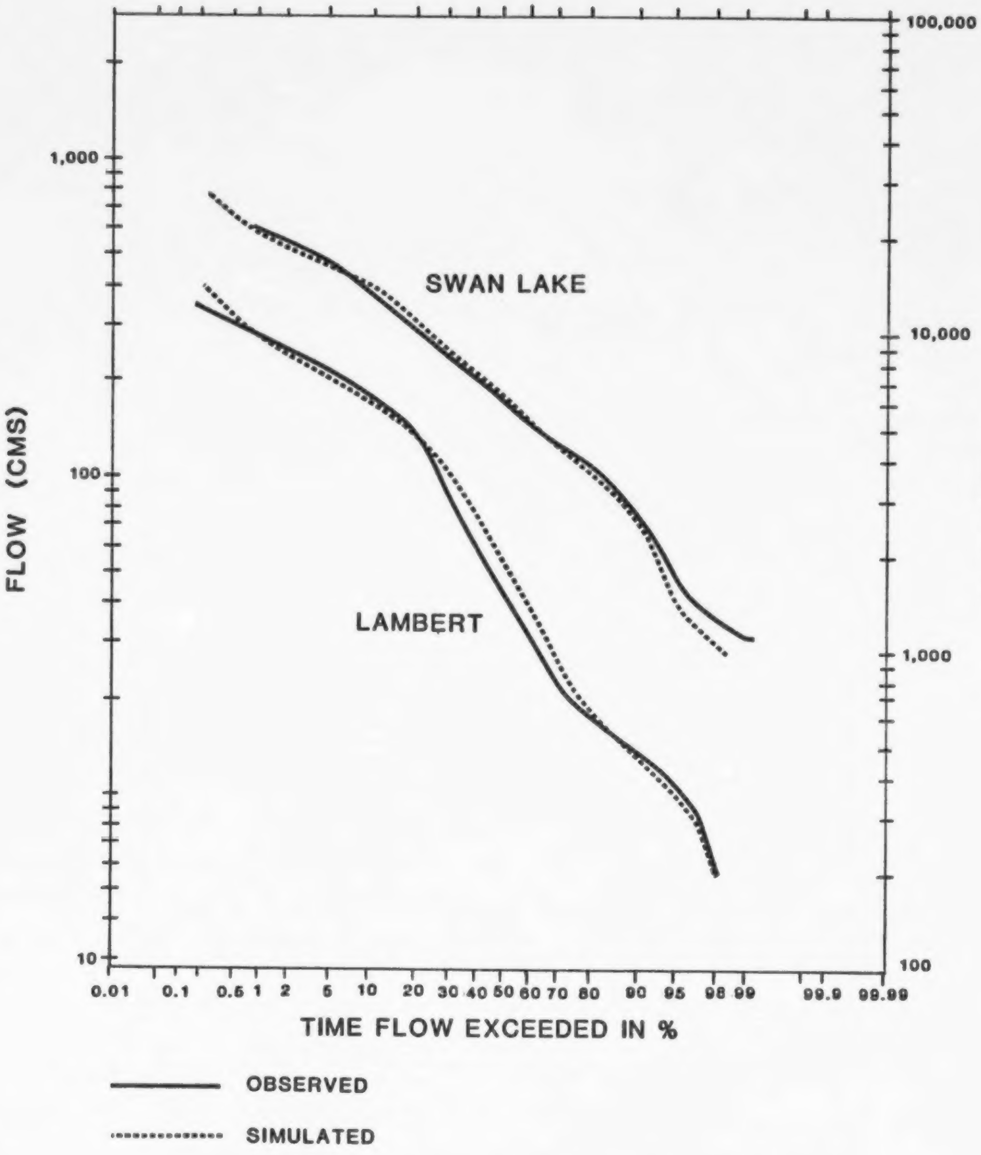


Figure 5.4 Observed vs. simulated flow frequencies (calibration).

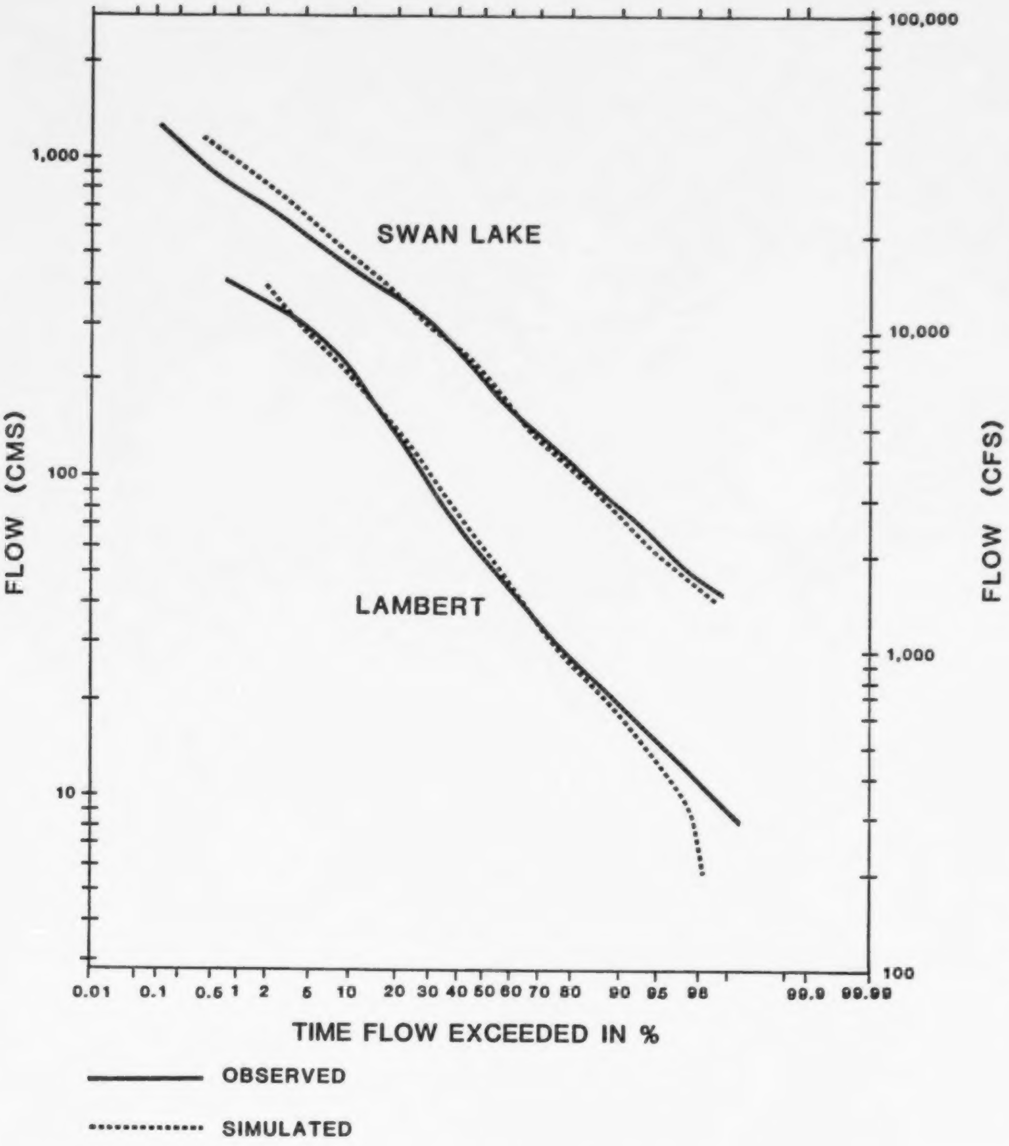


Figure 5.5 Observed vs. simulated flow frequencies (verification).

could be made. The divergences occurring at extreme low flow were deemed not important to the results of this study. To better characterize the upper portion of the watershed, a more comprehensive gaging network and simulation plan must be established. Currently, no precipitation gages exist north of Clarksdale, which sits at an almost equal latitude as the Lambert streamgage. The good representation of hydrology at Swan Lake was deemed adequate for the purposes of this study. The final hydrologic calibration parameters are listed in Table 5.4.

5.3 SEDIMENT CALIBRATION AND VERIFICATION

Following calibration and verification of basin hydrology, soil erosion and sediment transport calibration is the next step. The process is analogous to the hydrologic modeling effort. First, overland sediment transport is simulated to provide edge-of-stream loadings. Estimates can be made, or obtained, of gross erosion volumes by various techniques, and then used as an overall guide to assess simulated values for each PLS. Second, instream sediment transport calibration is performed by manipulation of channel sediment parameters to improve agreement with observed instream sediment data.

5.3.1 Edge-of-Stream Sediment Loadings

Before soil erosion calibrations were begun, erosion estimates were made for various locations within the study area. These estimates were made by the Soil Conservation Service in Mississippi and published for many regions within the state (USDA, 1982). The values reported by the SCS were for gross

TABLE 5.4 FINAL CALIBRATION HYDROLOGY INPUT PARAMETER SET* (English Units)

	P PLS 1 Bluff Forest	PLS 2 Bluff Pasture	PLS 3 Bluff Crop	PLS 4 Delta Forest	PLS 5 Delta Pasture	PLS 6 Delta Soybean	PLS 7 Delta Cotton
LZSN	5.0	4.5	4.5	5.5	5.0	5.0	5.0
INFILT	.20	.15	.08	.10	.10	.05	.05
LSUR	200.	300.	300.	500.	500.	500.	500.
SLSUR	.120	.050	.030	.0025	.0025	.0025	.0025
KVARY	.10	.10	.10	.20	.20	.20	.20
AGWRC	.97	.96	.96	.997	.992	.992	.992
DEEPFR	0.	0.	0.	.05	.05	.05	.05
BASETP	.10	.05	.05	.10	.05	.05	.05
AGWETP	.25	.05	.05	.15	.15	.15	.15
CEPSC	.20	.10	.04-.19	.20	.10	.03-.20	.05-.20
UZSN	.80	.50	.40-.80	.80	.50	.50-.80	.50-.80
NSUR	.35	.25	.25-.30	.35	.25	.25-.30	.25-.30
INTFW	2.5	2.0	2.0	3.0	2.5	2.5	2.5
IRC	.70	.60	.60	.85	.78	.78	.78
LZETP	.80	.35	.25-.70	.80	.35	.25-.70	.25-.70

* See HSPF Manual (Johanson et al., 1984) for parameter units.

erosion and were used as a general guide in determining valid simulated values. The Universal Soil Loss Equation used in making the SCS estimates is not considered valid for areas with extreme slopes (as those found in the bluff region) and usually provides values higher than the edge-of-stream loadings simulated by the model. Reported bluff erosion rates were therefore suspect and treated accordingly. Estimates for delta-region cropland ranged from 10. - 12.5 Tonnes/Ha while those for bluff-region cropland ranged from 30. - 55. Tonnes/Ha soil loss. Pasture land potential soil loss was much lower, with estimates for the delta between .15 - 1.0 Tonnes/Ha and for the bluff between 6.5 - 19. Tonnes/Ha. Gully erosion was reported as substantial in the bluffs (USDA, 1982, Keown, 1981, USDA, 1975) and minimal in the delta.

Table 5.5. shows the final simulated values of soil erosion rates for each PLS, including both sheet and gully losses. Gully erosion was not simulated in the delta. Values accepted for the calibration are less on the average than those estimated by the USLE for gross erosion because not all eroded soil will reach the stream channel. The values reported in Table 5.5 reflect actual sedimented delivery, or edge-of-stream loadings from the PLS to the channel reach. The period between 1973 and 1975 was very wet, resulting in high simulated erosion rates. Erosion rates for delta cropland averaged over the entire simulated period equal about 8.6 Tonnes/Ha, just below the range estimated by the USLE. Over the long run, this average would be lower, as fewer wet years would influence the sample. It should also be noted that the simulated period provides a very short record for developing average annual loads. Erosion loads are extremely variable from year to year. When USLE parameters are chosen, as per the guidelines, the estimated loads are based on a 22-year average, reflecting long-term weather cycles.

TABLE 5.5 SIMULATED SOIL EROSION RATES (Tonnes/Ha) FOR EACH PLS DURING BOTH CALIBRATION AND VERIFICATION PERIODS

Calibration

	PLS 1 Bluff Forest		PLS 2 Bluff Pasture		PLS 3 Bluff Crop		PLS 4 Delta Forest	PLS 5 Delta Pasture	PLS 6 Delta Soybean	PLS 7 Delta Cotton
	Sheet	Gully	Sheet	Gully	Sheet	Gully	Sheet	Sheet	Sheet	Sheet
1975	.26	.01	2.31	.58	9.48	4.33	1.54	3.05	19.30	12.50
1976	.27	.02	.47	.21	2.80	.41	.39	.91	4.19	3.18
1977	1.00	.32	1.39	6.43	14.70	12.70	.47	1.21	10.40	6.43
Average	.51	.12	1.39	2.41	8.99	5.81	.80	1.72	11.30	7.37

Verification

	PLS 1 Bluff Forest		PLS 2 Bluff Pasture		PLS 3 Bluff Crop		PLS 4 Delta Forest	PLS 5 Delta Pasture	PLS 6 Delta Soybean	PLS 7 Delta Cotton
	Sheet	Gully	Sheet	Gully	Sheet	Gully	Sheet	Sheet	Sheet	Sheet
1971	.23	.01	1.42	.39	6.34	2.06	.07	.10	2.19	.47
1972	.07	.00	.84	.12	4.59	.61	.46	.98	6.81	7.40
1973	1.36	.54	2.26	5.02	21.60	12.75	1.62	3.39	12.86	10.24
1974	.37	.53	1.34	5.13	19.45	10.47	.62	1.42	11.72	12.04
Average	.51	.27	1.46	2.66	13.00	6.47	.69	1.47	8.40	7.54

5.3.2 Instream Sediment Simulation

The final process to be calibrated was instream sediment transport. Here both the aggradation and degradation processes must be kept in balance and the suspended sediment concentation must approach measured values. During the simulation period samples were collected between March 1973 and February 1976. At Lambert, 24 samples were taken during the calibration period and 28 samples during the verification period. At Swan Lake, 38 samples were gathered during the calibration period and 32 samples during the verification period. Samples were obtained every 1-2 weeks. No storm events were continuously sampled. Few samples were taken during large runoff events, resulting in a limited population of sediment concentration values. Figures 5.6 and 5.7 show observed and simulated sediment concentration frequency curves for both Lambert and Swan Lake during calibration and verification periods. The observed distributions cover a much shorter range than those predicted by simulation due to limited data collection activities. Simulated curves were fit as close as possible to the observed distribution by adjusting critical shear-stress values for deposition and scour, and the stream channel erodibility factor.

While attempting to match instream sediment concentration values, other criteria were maintained to produce a successful calibration. By monitoring changes in streambed composition and aggradation/degradation trends, simulated results could be matched to known channel processes. In general, the major channel of the Yazoo River system is slowly aggrading while many tributary streams coming from the bluff area are degrading (Larry Banks, personal communication, 1984). During

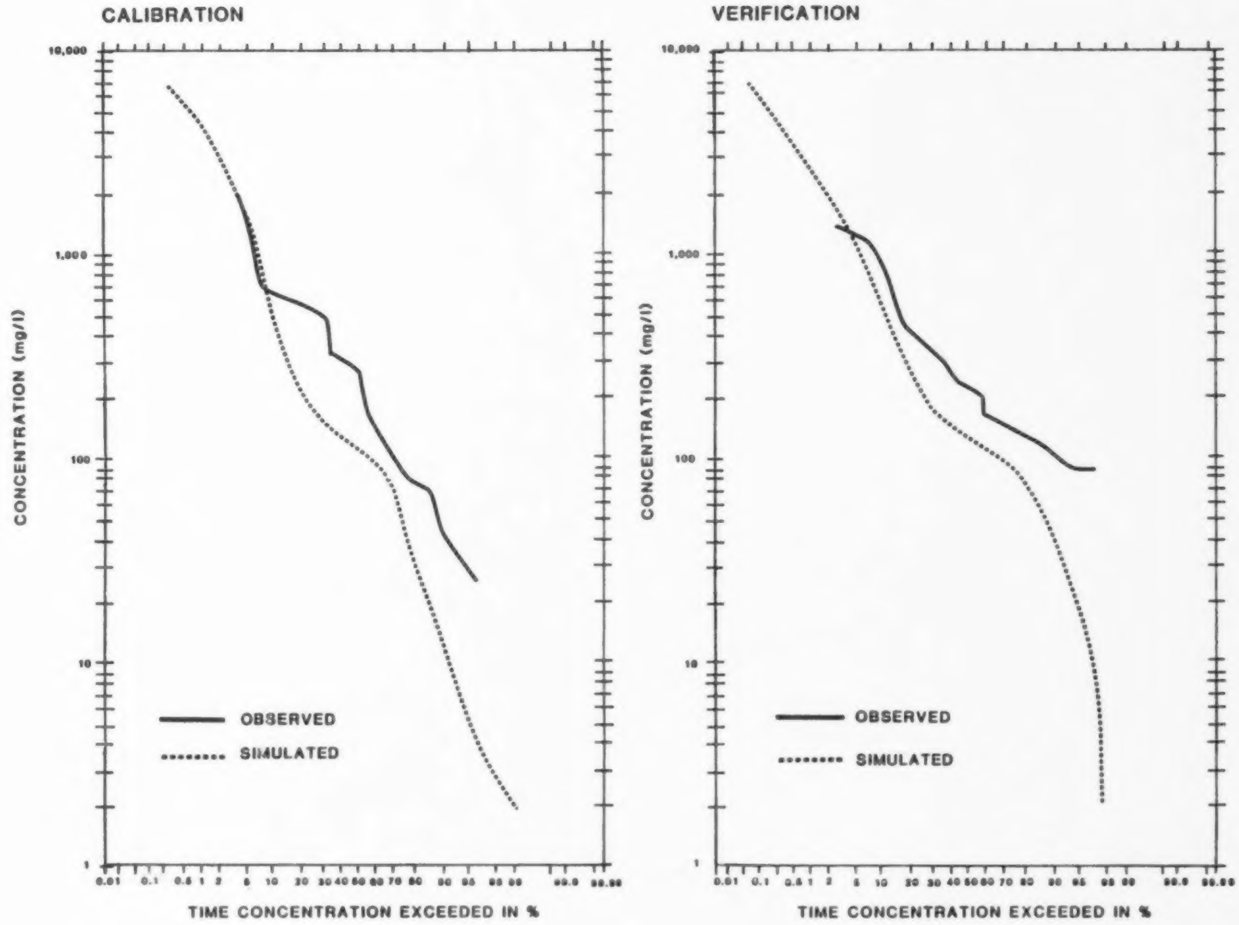


Figure 5.6 Observed vs. simulated suspended sediment at Lambert.

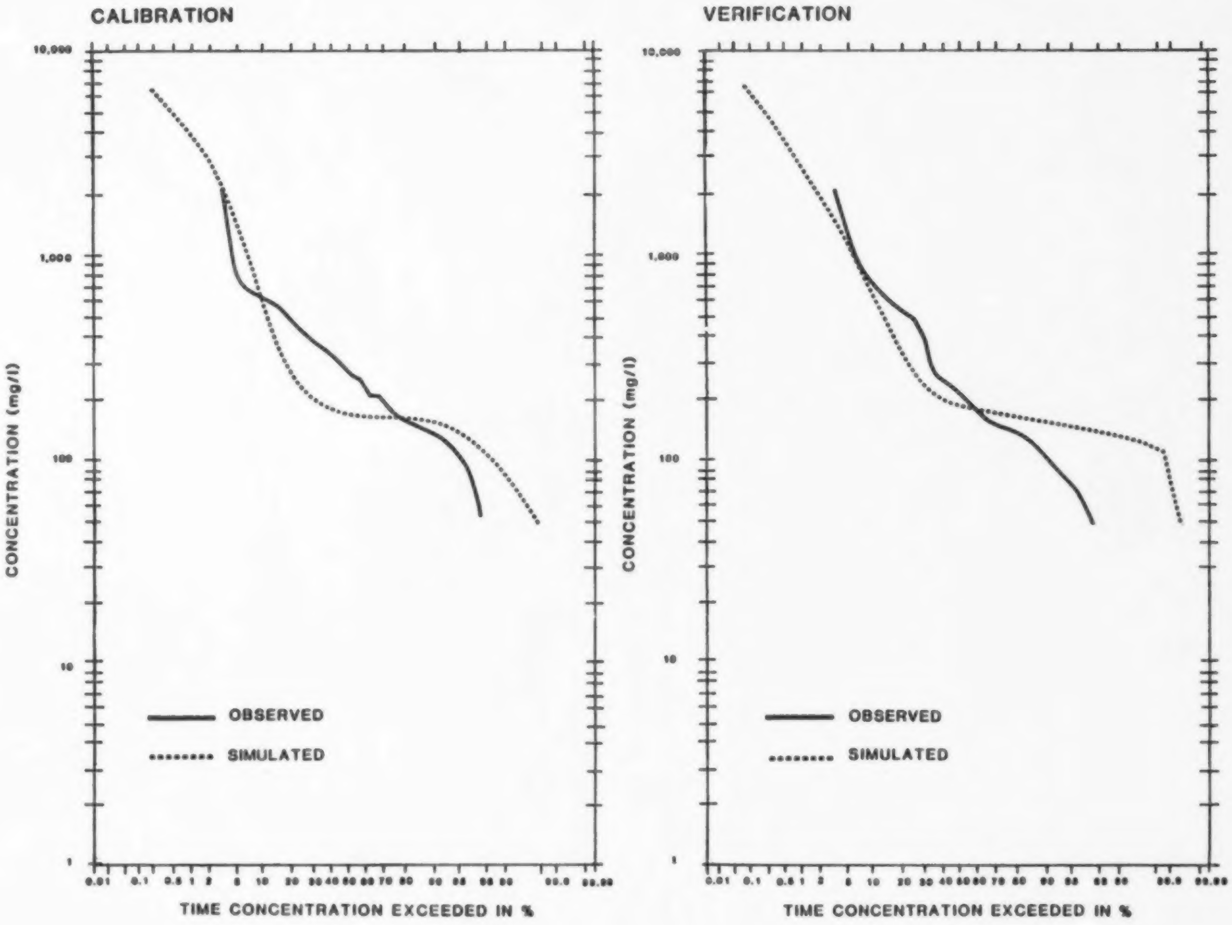


Figure 5.7 Observed vs. simulated suspended sediment at Swan Lake.

both the calibration and verification periods the upper 3 reaches maintained stable streambeds, reach 4 flowing out of the bluffs slowly degraded, and the bottom reach slowly aggraded. In all cases the streambed sand/silt/clay composition remained fairly constant, with a slow shift to a sandier mix. By comparing the overall contribution of sediment from overland flow to the total load simulated at the bottom of the watershed, a slow simulated aggradation process was shown to take place.

The sediment mass balance can be seen in Table 5.6. HSPF provided values for total suspended sediment leaving the study area, as well as the contribution to the stream channels from the land surface. The difference between these two values provides the contribution of sediment from the stream channel itself. Overall, a slight aggradation process is seen to take place which conforms to observations mentioned earlier.

The final calibration of erosion and sediment transport processes was considered satisfactory. General knowledge of basin-wide characteristics allowed qualitative criteria to be matched, such as the relative stability of streambanks, while a small collection of hard data provided a target for sediment concentration values. Although the observed sediment concentration frequency distributions were not matched closely, as with the hydrology simulation, they were deemed acceptable owing to the small amount of data available for comparison. The final soil erosion and sediment transport calibration parameters are listed in Tables 5.7 and 5.8.

TABLE 5.6 SIMULATED ANNUAL SEDIMENT MASS BALANCE

Calibration

	Simulated Sediment Loads (Tonne/Ha)		
	Total Load @ Watershed Outlet	Load from Land Surface	Load from Stream Channel
1975	6.55	8.34	-1.79
1976	1.90	1.96	- .06
1977	4.62	6.57	-1.95

Verification

	Total Load @ Watershed Outlet	Load from Land Surface	Load from Stream Channel
1971	1.88	1.47	+ .41
1972	2.96	3.29	- .34
1973	7.73	8.72	- .99
1974	6.66	7.66	-1.01

TABLE 5.7 FINAL CALIBRATION SOIL EROSION INPUT PARAMETER SET*
(English Units)

PERLND Module - Section SEDMNT

Parameter	PLS 1 Bluff Forest	PLS 2 Bluff Pasture	PLS 3 Bluff Crop	PLS 4 Delta Forest	PLS 5 Delta Pasture	PLS 6 Delta Soybean	PLS 7 Delta Cotton
KRER	.20	.30	.40	.15	.20	.37	.37
JRER	2.00	2.00	2.00	2.00	2.00	2.00	2.00
AFFIX	.00	.00	.003	.00	.00	.003	.003
COVER	.95	.90	.05-.80	.95	.90	.05-.80	.05-.80
KSER	5.0	5.0	10.0	2.0	1.5	6.0	6.0
JSER	1.6	1.6	1.6	1.6	1.8	1.7	1.7
KGER	2.0	5.0	7.0	.00	.00	.00	.00
JGER	2.2	2.2	2.2	2.2	2.2	2.2	2.2
DETS			1.5-3.0			1.5-3.0	1.5-3.0

* See HSPF Manual (Johanson et al., 1984) for parameter units.

TABLE 5.8 FINAL CALIBRATION CHANNEL SEDIMENT TRANSPORT INPUT PARAMETER SET* (English Units)

RCHRES Module - Section SEDTRN

Sand

Parameter	RCH 1	RCH 2	RCH 3	RCH 4	RCH 5
D	.014	.014	.014	.014	.014
W	1.5	1.5	1.5	1.5	1.5
RHO	2.65	2.65	2.65	2.65	2.65
Silt					
D	.00063	.00063	.00063	.00063	.00063
W	.003	.003	.003	.003	.003
RHO	2.2	2.2	2.2	2.2	2.2
TAUCD	.02	.02	.02	.02	.15
TAUCS	.03	.03	.45	.45	.45
M	.15	.15	.15	.15	.20
Clay					
D	.000055	.000055	.000055	.000055	.000055
W	.000022	.000022	.000022	.000022	.000022
RHO	2.0	2.0	2.0	2.0	2.0
TAUCD	.015	.015	.015	.015	.008
TAUCS	.025	.025	.035	.035	.015
M	.008	.008	.008	.008	.010

* See HSPF Manual (Johanson et al., 1984) for parameter units.

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APPENDIX I

Honey Creek, Ohio

Watershed Data, Segmentation, and HSPF Calibration/Verification Report

ABSTRACT

The EPA Hydrological Simulation Program - FORTRAN (HSPF) was applied to the Honey Creek Basin in Ohio as part of the development of a methodology to estimate pesticide runoff and resulting instream concentrations from agricultural cropland in various regions of the United States. Honey Creek was shown chosen as representative of watersheds in the Eastern Cornbelt Region. HSPF was calibrated and verified for hydrology, hydraulics, sediment erosion, and instream sediment transport as a basis for performing sensitivity analyses on key pesticide chemical parameters.

This report describes the watershed data available for simulation, the segmentation plan for dividing the study area into land and channel segments, and the results of the calibration and verification efforts. In general, this study produced a good to very good hydrologic calibration and verification and a good sediment simulation. The model results for both hydrology and sediment were considered quite acceptable for the purposes of this study.

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Dr. David Baker, the Director of the Water Quality Laboratory at Heidelberg College in Tiffin, Ohio, provided alot of useful information and data collected in the Honey Creek Basin. His advice and assistance is greatly appreciated. SCS Extension Service agents Wenrich Stuckey Jr. (Seneca Co., Ohio) and Robert Smith (Crawford Co., Ohio) provided valuable information on crop acreages in the counties in which the Honey Creek Basin is located.

At Anderson-Nichols, Mr. Dan Meier was Project Engineer on this task of applying HSPF to the Honey Creek Basin. He was responsible for model calibration and report preparation under the general guidance and review of the Project Manager, Mr. Anthony Donigian. Mr. David Biggers was responsible for initial data base preparation. Mr. Mark Hersh assisted in other data preparation tasks, and Mr. Douglas Beyerlein provided guidance in general model application and calibration. Ms. Susan Reutter-Harrah directed the final preparation of the document with text editing performed by Ms. Arinthia L. Jones and with figures and charts prepared by Ms. Marythomas Hutchins. The dedication and efforts of these individuals contributed to the success of this study and is sincerely appreciated.

SECTION 1

INTRODUCTION AND EXECUTIVE SUMMARY

The application of HSPF to the Honey Creek Basin was undertaken as part of the parent study, described in the body of this report, to develop procedures for estimating the likely magnitude and variability of instream pesticide concentrations and pesticide runoff from cropland in selected agricultural regions of the U.S. The overall approach was to evaluate the characteristics of "representative" agricultural watersheds within each region, perform sensitivity analyses using HSPF for a range of selected chemical properties, and transform the model results into a series of curves for estimating (1) the frequency and duration of pesticide concentrations at a watershed outlet, and (2) pesticide runoff from the associated cropland; to use the curves the only information needed is chemical properties and the chemical application rate. To provide a sound basis for the methodology HSPF was applied to actual watersheds within each agricultural region as a demonstration of its ability to simulate chemical transport processes on agricultural watersheds throughout the country. The Honey Creek Basin was selected as the HSPF application site within the Eastern Cornbelt Region.

1.1 STUDY OBJECTIVES

Within the framework of the study described above, the objectives of the HSPF application to the Honey Creek Basin were as follows:

a. demonstrate the ability of HSPF to model the hydrologic, hydraulic, sediment erosion, and sediment transport behavior of an agricultural watershed characteristic of the Eastern Cornbelt Region;

b. estimate selected model parameters, which are usually evaluated through calibration, as a basis for determining representative parameter values for the region.

Pesticide simulation was not performed as part of this application due to the lack of observed pesticide data for comparison with model results and lack of adequate project resources; however, previous studies with HSPF (Donigian et al., 1983) and with predecessor models (Donigian et al., 1977) have sufficiently confirmed the pesticide simulation capabilities of HSPF for the purposes of this project.

The Honey Creek Basin was selected as an application site because of its location in the Eastern Cornbelt Region, its agricultural land, its status as a research watershed, and the availability of a reasonably adequate data base for model application.

The pesticide assessment methodology developed in the parent study provides a screening-level type analysis with order-of-magnitude accuracy in its predictions. Consequently, a

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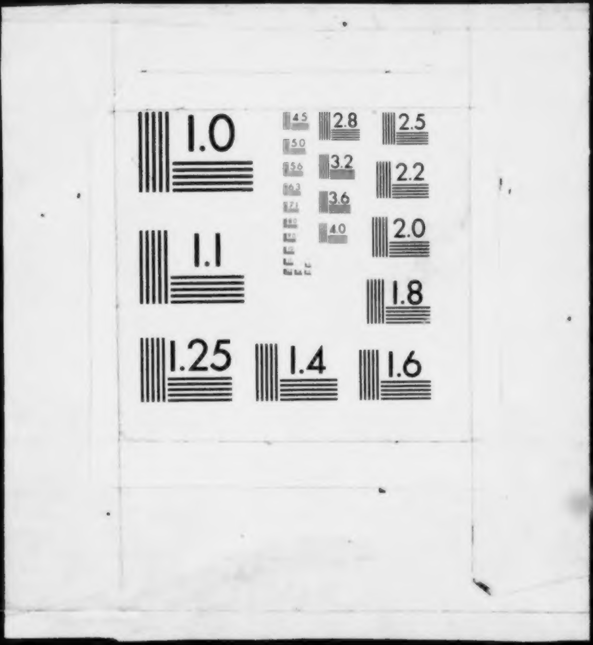
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greater degree of latitude was possible in the needed accuracy of the HSPF calibration than would have been allowable for more detailed and demanding planning, design, or watershed management purposes. Also, resource limitations required restrictions on the level of calibration. However, the model results are consistent with and well suited to the overall objectives and framework of this study.

1.2 REPORT CONTENT

The remainder of this introductory section provides an overall summary of the results of the HSPF application to the Honey Creek Basin, followed by conclusions and recommendations for future improvements in the simulation. The body of this appendix begins with the watershed and study area descriptions in Section 2, and the discussion of available data for modeling in Section 3. Section 4 describes the HSPF representation of the watershed through segmentation of the land area, based on meteorologic, edaphic, and land use characteristics, and segmentation of the stream channel. The approach and results of the calibration/verification exercise is then described in Section 5.

1.3 SUMMARY OF RESULTS

The Honey Creek Basin used in this study is located in north central Ohio and has a drainage area of 392.1 sq. km (151.4 sq. mi.). Approximately 60% of the basin is used for cropland and another 22% is in pasture and other agricultural uses. Approximately 10% of the watershed is forested. The remaining area is in wetlands, lakes and urban areas.

HSPF was used to simulate the flow and sediment transport processes in the Honey Creek Basin. The final set of model parameters (with minor modifications) was then used to represent the Eastern Cornbelt Region.

The hydrologic response of the watershed was calibrated by comparing simulated streamflow with observed flow records over a 2-year 10-month period; parameters were adjusted until an acceptable match was obtained. Comparisons of simulated and observed annual volumes and peak flows, and flow frequency duration analyses were performed with fair to very good results. The final hydrologic parameter set was verified over a 2-year 11-month period and produced fair to good results.

Soil erosion parameters were calibrated by comparing simulated annual sediment washoff to annual gross erosion estimates for various land uses in the Honey Creek Basin over the 2-year 10-month period. Instream sediment transport was calibrated by comparing simulated sediment concentrations to observed concentration data. Concentration comparisons were made in the form of frequency duration curves. Overall, the sediment calibration was considered good, based on a general understanding of stream behavior in the region. The final sediment parameter set was verified over a 2-year 11-month period and provided results similar to those of the calibration period.

1.4 CONCLUSIONS AND RECOMMENDATIONS

HSPF was used successfully to model hydrology and sediment in the Honey Creek Basin. Although the simulation was adequate for the purposes of this study, several problems were encountered, some of which should be resolved in future studies. There is a lack of meteorologic data collected within the watershed. All data time series used in the simulation were from gages located 8-97 km (5-60 mi.) outside of the basin boundary. Particularly, this caused problems with representation of localized rainfall in the basin. The use of more precipitation records and greater segmenting of the basin may lead to better rainfall representation though this would also increase the complexity and cost of the computer runs.

The length of the available streamflow record was quite short (5 years, 9 months) and was the limiting factor in determining the length of the simulation period. The calibration and verification periods were both less than three years in length, making simulation of the basin over a wide range of conditions impossible.

By adequately reproducing the observed runoff frequencies for the simulation period, it was possible to achieve a successful reproduction of observed sediment concentration frequencies. The HSPF simulation of both land surface erosion and instream sediment processes was reasonable. However, the brevity of the simulation period made it impossible to model the sediment processes over a wide range of meteorologic and runoff conditions.

Having produced adequate hydrologic and sediment representation of the study area, the linking of chemical transport to these mechanisms should provide realistic forecasts of pesticide movement through similar basins.

SECTION 2

WATERSHED DESCRIPTION

2.1 LOCATION, SIZE, AND SURFACE PHYSIOGRAPHY

The Honey Creek Watershed is located in Seneca, Crawford, and Huron Counties, Ohio. The basin lies in the Till Plain area of the central lowlands physiographic region, which includes most of the glaciated part of Ohio. Honey Creek flows west to the Sandusky River which flows north to Lake Erie as shown in Figure 2.1.

The basin used in this study has a drainage area of 392.1 sq. km. (151.4 sq. mi.) as defined by the most downstream point having recorded streamflow data sufficient for modeling purposes.

The surface physiography of the Honey Creek basin is characterized by glacial deposition with most of the area covered by ground moraine, terminal moraine, lacustrine deposition, glacial outwash, flood plains, and glacial drift. Elevations range from 348 meters (1140 ft) above MSL in the southeast to 250 meters (820 ft) above MSL at the western outlet of the study basin. Relief in the watershed is mainly

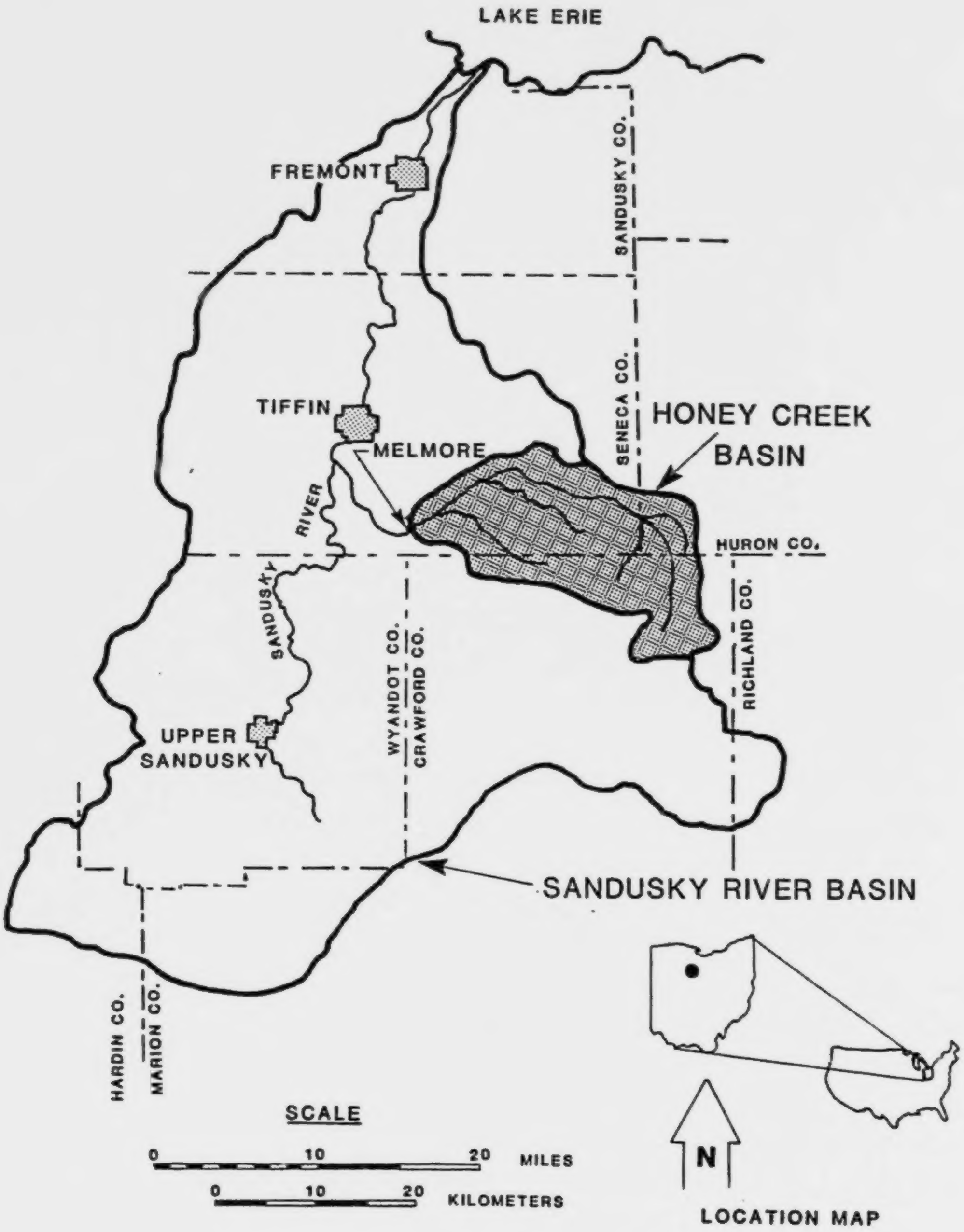

LAKE ERIE
FREMONT
SANDUSKY CO.
SENECA CO.
TIFFIN
MELMORE
HONEY CREEK BASIN
SANDUSKY RIVER
HURON CO.
RICHLAND CO.
WYANDOT CO.
CRAWFORD CO.
UPPER SANDUSKY
SANDUSKY RIVER BASIN
HARDIN CO.
MARION CO.
SCALE
0
10
20
MILES
0
10
20
KILOMETERS
N
LOCATION MAP

Figure 2.1 Honey Creek Basin.

nearly level to undulating.

The headwaters of Honey Creek originate in a large swampy area, the remains of a glacial lake. The creek flows from its headwaters to the north along the eastern side of its basin and then to the west along the northern side of its basin. All tributaries discharge to Honey Creek from the southeast, south, and southwest.

2.2 CLIMATE

The Honey Creek basin experiences cold winters and uncomfortably warm summers. The annual average monthly air temperature is 10.6 deg. C (51 deg. F) with average monthly minimum and maximum temperatures ranging from -6.7 deg. C (20 deg. F) for January to 29.4 deg. C (85 deg. F) for July. The average frost-free season is 160 days (U.S. Dept. of Commerce, 1968).

Average annual precipitation in the basin is approximately 91 cm (36 in.) as shown in Figure 2.2. Average monthly rainfall ranges from approximately 5 cm (2 in.) for December to 10 cm (4 in.) for June (U.S. Dept. of Commerce, 1968). The wettest months are May and June; the driest months are November and December. Average annual snowfall in the basin is 79 cm (31 in.) (Ohio Dept. of Natural Resources, 1967).

Average annual pan evaporation in the basin is approximately 109 cm (43 in.) (U.S. Dept. of Commerce, 1968).

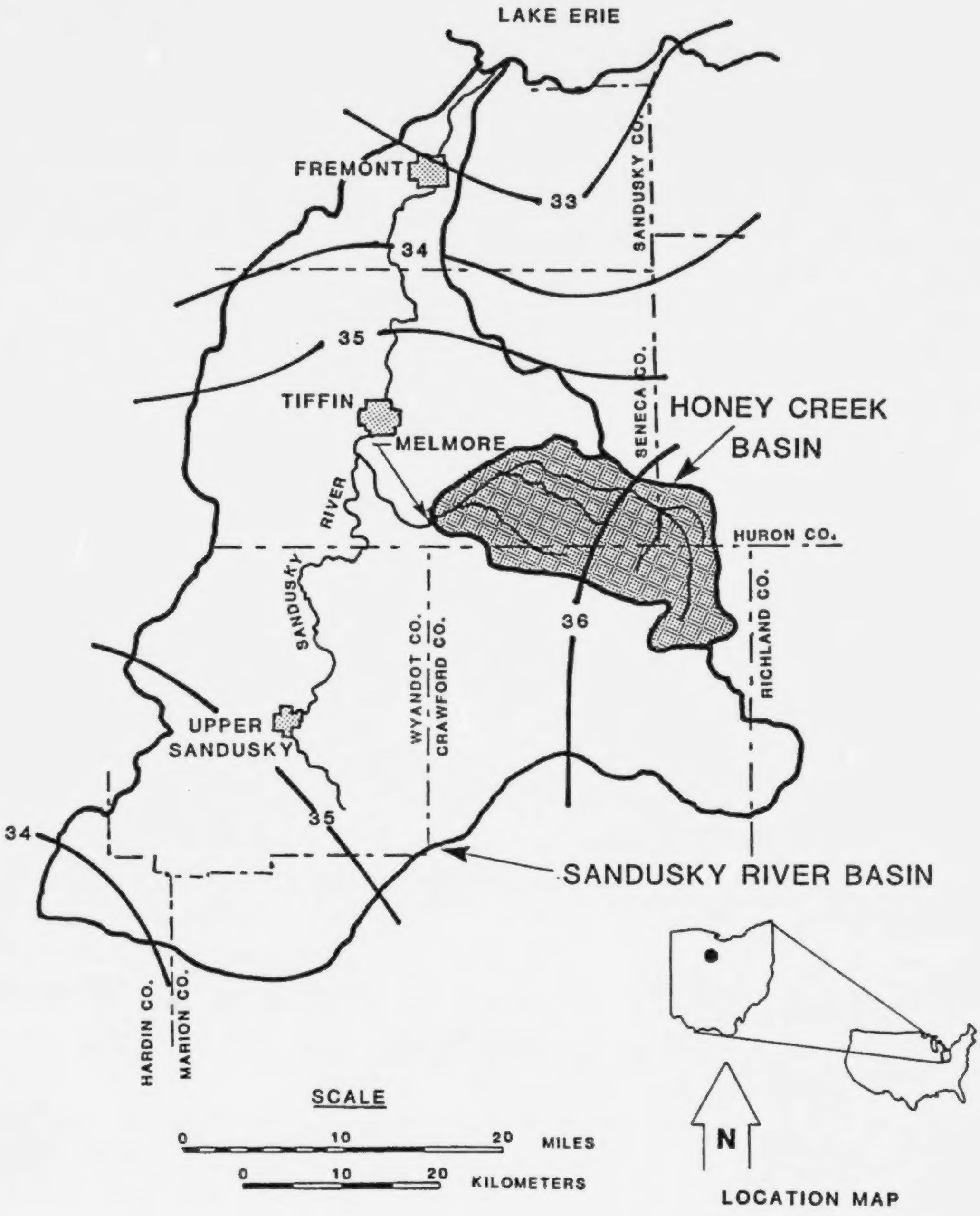

LAKE ERIE
FREMONT
33
SANDUSKY CO.
34
35
TIFFIN
MELMORE
SENECA CO.
HONEY CREEK BASIN
RIVER
SANDUSKY
HURON CO.
36
WYANDOT CO.
CRAWFORD CO.
RICHLAND CO.
UPPER SANDUSKY
34
35
SANDUSKY RIVER BASIN
HARDIN CO.
MARION CO.
SCALE
0 10 20 MILES
0 10 20 KILOMETERS
N
LOCATION MAP

Figure 2.2 Mean annual precipitation (in.) in the Sandusky River Basin, Ohio. (Ohio Dept. of Natural Resources, 1967).

2.3 SOILS AND GEOLOGY

The soils in the Honey Creek watershed are relatively homogeneous across the basin. Typically they consist of poorly drained silt loams on slopes of 0 to 2%. However, the flat, high water table soils are very productive when drained.

The predominant upland soil series are the Tiro, Bennington, and Blount series. These soils consist of deep, somewhat poorly drained silt loams that formed in lacustrine and alluvial sediments and glacial till. Permeability is slow to moderate. Runoff is slow to medium. Available water capacity and organic matter content are moderate. The seasonal high water table is perched at a depth of 30-76 cm (12-30 in.) in winter, spring, and other extended wet periods (Ernst et al., 1980; Steiger et al., 1979).

A narrow band of deep, well drained to somewhat poorly drained silt loams occurs along the main branch of Honey Creek. These soils are predominantly of the Shoals and Chagrin series. Permeability is moderate. Runoff is slow. Available water capacity is high. Organic matter content is moderate. The seasonal high water table is at a depth of 30-91 cm (12-36 in.) in winter, spring, and other extended wet periods. These soils are often flooded for brief periods in fall, winter, and spring (Ernst et al., 1980; Steiger et al., 1979).

Some properties of these particular soil types are given in Table 2.1.

The bedrock underlying the Honey Creek Basin consists of Silurian-age carbonate rocks, chiefly dolomite with some limestone deposits, which crop out or lie beneath glacial deposits of varying thickness (Norris, 1975). These limestone

TABLE 2.1 PHYSICAL AND CHEMICAL PROPERTIES OF SOILS IN THE HONEY CREEK BASIN (Ernst, et al., 1980)

Soil Name	Depth	Permeability	Available Water Capacity	Soil Reaction	Shrink-Swell Potential	Erosion Factors K	Erosion Factors T
	In	In/hr	In/in	pH			
			Upland				
Bennington	0-9	0.6-2.0	0.17-0.21	5.1-6.5	Low	0.43	3
	9-34	0.06-0.6	0.10-0.17	4.5-7.8	Moderate	0.32	
	34-60	0.06-0.2	0.07-0.12	7.4-8.4	Low	0.32	
Blount	0-7	0.6-2.0	0.20-0.24	5.1-6.5	Low	0.43	3
	7-30	0.06-0.6	0.06-0.10	4.5-7.8	Moderate	0.43	
	34-60	0.06-0.6	0.07-0.10	7.4-8.4	Low	0.43	
Tiro	0-9	0.6-2.0	0.21-0.24	5.6-7.3	Low	0.37	4
	9-30	0.6-2.0	0.17-0.21	4.5-6.5	Moderate	0.37	
	30-60	0.06-0.6	0.06-0.10	6.6-7.8	Low	0.37	
			Lowland				
Chagrin	0-9	0.6-2.0	0.20-0.24	5.6-7.3	Low	0.32	5
	9-28	0.6-2.0	0.14-0.20	5.6-7.3	Low	0.32	
	28-60	0.6-2.0	0.08-0.20	5.6-7.3	Low	0.32	
Shoals	0-8	0.6-2.0	0.22-0.24	6.1-7.8	Low	0.37	5
	8-40	0.6-2.0	0.17-0.22	6.1-7.8	Low	0.37	
	40-60	0.6-2.0	0.12-0.21	6.6-7.8	Low	0.37	

and dolomite beds constitute aquifers which form a regional flow system. Movement of ground water north towards Lake Erie along the Cincinnati arch, a north-plunging regional anticline, is largely the cause of high water table conditions in most of the Honey Creek Basin (Norris, 1974).

2.4 LAND USES AND MANAGEMENT

The Honey Creek Basin is located in the Eastern Cornbelt Region which covers most of Ohio and Indiana and parts of Western Pennsylvania and Eastern Illinois. The watershed is representative of many flat to undulating agricultural areas in the Great Lakes Basin and northeastern drainage area of the Mississippi River. Approximately 60% of the study watershed is in major crops, 22% in pasture and other agricultural uses, 10% in forest, and the remaining 8% in wetlands, lakes, and urban areas (Cahill et al., 1979; Stuckey, 1983; Smith, 1983). Table 2.2 lists the areas of the various land uses in the basin.

The major agricultural crops grown in the basin are corn and soybeans, with smaller acreages in wheat and oats. Extensive subsurface tile drain networks (0.9-1.5 m below surface) have been installed throughout the watershed to drain the high water table soils. The surface drainage greatly increases the productivity of the soil. Also, experiments on trial plots with tile drainage show an average long-term reduction in peak flow of 41% compared to plots with no tile drainage (McLean and Schwab, 1982). Typical tillage practices for major crops are listed in Table 2.3.

Small forested areas, mostly deciduous, are scattered throughout the watershed on abandoned agricultural fields and

TABLE 2.2 LAND USE AREAS IN THE HONEY CREEK BASIN (Cahill, et al., 1979; Stuckey, 1983; Smith, 1983)

Land Use	Area ha	ac	%
Crop	23,422	57,875	59.7
Pasture, other agricultural use	8,634	21,334	22.0
Forest	4,096	10,122	10.4
Wetland	840	2,076	2.2
Water	392	969	1.0
Urban	1,848	4,566	4.7
Total	39,232 (392.1 sq. km)	96,942 (151.4 sq. mi.)	100.0

TABLE 2.3 TYPICAL TILLAGE PRACTICES FOR MAJOR CROPS IN THE HONEY CREEK BASIN (Cahill, et al., 1979)

Month	Corn	Soybeans
Jan		
Feb		
Mar		
Apr	Moldboard Plow Disc, Plant	
May		Moldboard Plow Disc, Plant
Jun	Cultivate	
Jul		Cultivate
Aug		
Sep		
Oct		Harvest, Disc
Nov	Harvest, Disk	
Dec		

in several small wetland areas located along stream channels.

Pasturelands are located on abandoned cropland as well as on soils not suitable for crops. Little or no tillage is performed.

Wetlands, farm ponds, and urban areas are not of sufficient extent to have a large impact on the hydrologic and erosion/sedimentation characteristics of the basin.

2.5 WATER RESOURCES

2.5.1 Water Supply

There is evidence of deep ground-water movement from the Scioto River Basin northward into the Sandusky River Basin, beneath the topographic divide separating these two basins. Furthermore, a high ground-water yield area of highly permeable strata underlies most of the Sandusky River Basin as well as a substantial portion of the Honey Creek Basin. Thus, it is likely that an undetermined amount of ground water flows into the Honey Creek Basin beneath its southern drainage divide; likewise, an undetermined amount of ground water may flow northward out of the basin. Existing data is insufficient to determine whether there is a net gain or loss of ground water from the Honey Creek Basin (Norris, 1974).

There is no artificial interbasin transfer of water into or out of the Honey Creek Basin (for example, via irrigation systems). Thus, the majority of water in the watershed originates from precipitation.

2.5.2 Water Quality

Pesticide residues are present in Honey Creek during the months of May and June. The highest concentrations occur during the first runoff event following pesticide applications associated with planting. Much lower concentrations are produced by subsequent runoff events (Baker, 1983). Table 2.4 lists the peak pesticide concentrations observed at Melmore from April to August of 1982.

Ground water in the Honey Creek Basin is of the calcium bicarbonate type due to the carbonate strata underlying the watershed (Norris, 1974).

TABLE 2.4 PEAK PESTICIDE CONCENTRATIONS IN HONEY CREEK OBSERVED AT MELMORE DURING THE APRIL - AUGUST SAMPLING PERIOD IN 1982 (Baker, 1983)

Pesticide	Concentration μg/L	Date
Linuron	13.1	05/25
EPTC	.82	05/25
Butylate	.213	05/24
Ethoprop	1.13	05/17
DIA	4.65	05/25
DEA	3.31	05/24
Treflan	.093	06/03
Phorate	.022	05/28
Simazine	3.60	06/29
Atrazine	48.4	05/25
Terbufos	.124	07/08
Fonofos	.024	05/26
Diazinon	.008	06/29
Cyanazine	14.9	05/25
Metribuzin	8.24	05/25
Alachlor	69.6	05/25
Metolachlor	90.8	05/28
Chlorpyrifos	2.69	05/29
Penoxalin	.65	05/27

Based on 63 samples

SECTION 3

AVAILABILITY AND SELECTION OF TIME SERIES DATA

3.1 HSPF TIME SERIES DATA REQUIREMENTS

Hydrologic and sediment simulation with HSPF requires the following time series data:

1. precipitation
2. evaporation
3. streamflow (for comparison with simulated results)
4. water temperature
5. sediment (for comparison with simulated results)
6. air temperature
7. wind speed
8. solar radiation
9. dewpoint temperature

Of these, air temperature, wind speed, solar radiation, and dewpoint temperature are all used primarily in HSPF snowmelt calculations. Since snowfall occurs in the Honey Creek Basin, all of the above time series were needed for this simulation.

3.2 AVAILABLE DATA

The National Oceanic Atmospheric Administration (NOAA) National Weather Service (NWS) maintains a number of weather stations near the Honey Creek Basin. Sixteen of these stations and the type of data available at each station are listed in Table 3.1 and the location of each station in relation to the watershed boundary is shown in Figure 3.1.

The Water Quality Laboratory at Heidelberg College in Tiffin, Ohio maintains three recording rain gages in or near the Honey Creek Basin (Figure 3.1). The Water Quality Laboratory also collects data from a "farmers' network" of non-recording rain gages maintained by 21 local farmers in the Honey Creek Basin.

As shown in Table 3.1, Class A pan evaporation, daily maximum and minimum air temperatures, and other meteorologic data including wind speed are collected at several NWS stations near the Honey Creek Basin. Evaporation and wind speed data from these stations are only available for non-winter months.

Additional meteorologic data are available from two agricultural research stations located 95-130 km (60-80 mi.) southwest of the Honey Creek Basin. The Wooster Agricultural Research Station and the Coshocton Agricultural Research Station collect humidity, pan evaporation, solar and net radiation, and wind data. Neither station collects pan evaporation during the winter months.

The locations of two streamflow gages maintained by the United States Geologic Survey are shown in Figure 3.2. Drainage areas and period of record information for the two gages are given in Table 3.2. Water levels are monitored at 5-minute intervals; from this data, mean daily streamflow (in inches

TABLE 3.1 NWS STATION INDEX FOR HONEY CREEK BASIN METEOROLOGIC DATA (U.S. Weather bureau, 1980)

Station	Meteorologic Data	Period of Record B
Ashland 2 SW	P,T	1941 - present
Bucyrus	P*,T	1941 - present
Charles Mill Lake	P,T,E,O	1941 - present
Findlay FAA AP	P*,T,O	1941 - present
Findlay Sewage Plant	P,T	1941 - present
Fremont	P,T	1941 - present
Galion Water Works	P,T	1941 - present
Hoytville 2 NE	P,T,E,O	1941 - present
Mansfield 5 W	P*,T	1941 - present
Mansfield WSO AP	P,T,E,O	1941 - present
Norwalk 5 SE	P	1941 - present
Norwalk Sewage Plant	P*,T	1941 - present
Plymouth 2 WSW	P*,T	1941 - present
Tiffin	P*,T	1941 - present

Legend:

P = hourly precipitation

P* = daily precipitation from non-recording gage

T = daily maximum/minimum temperature

E = daily class A pan evaporation

O = other meterologic data (eg. wind speed)

Footnote:

A - An hourly record is included in the Hourly Precipitation Climatological Data Series.

B - Data starting in 1941 were used to generate normal values; actual period of record may be longer.

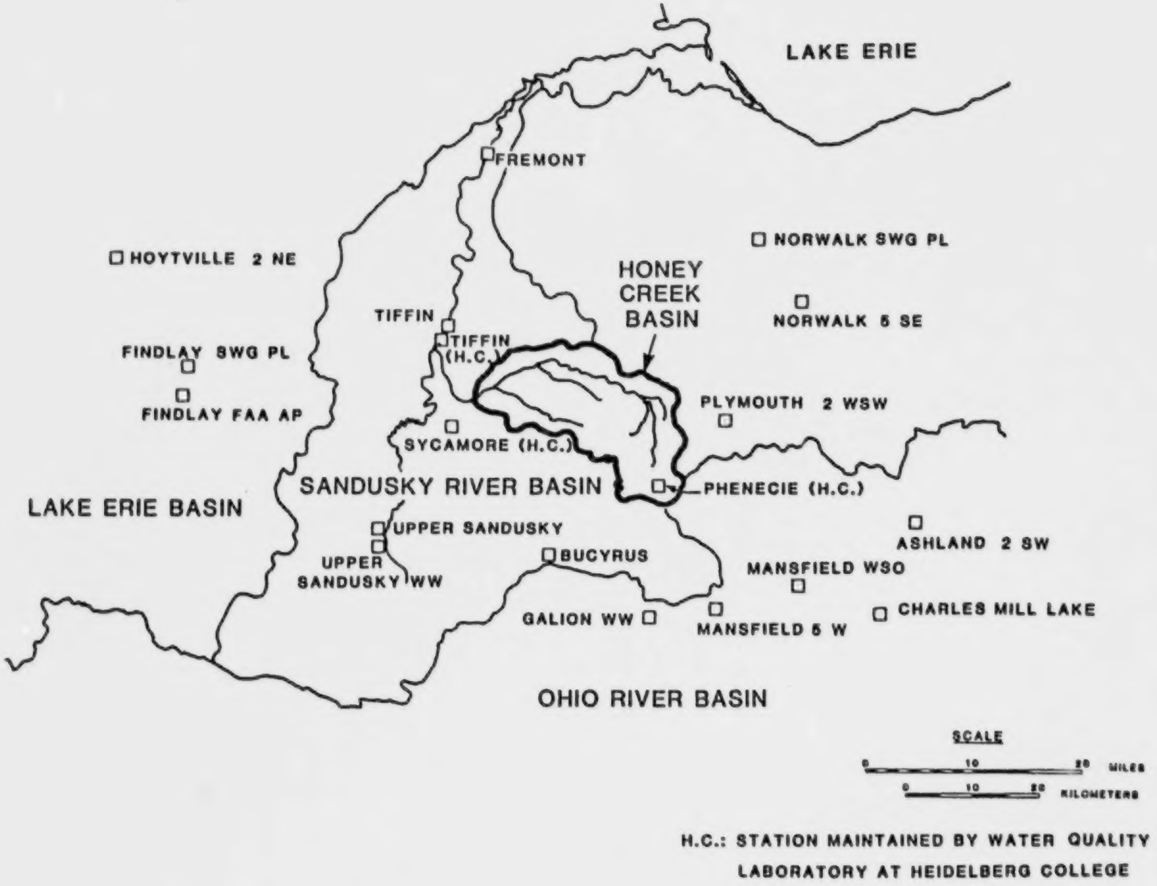

LAKE ERIE
FREMONT
HOYTVILLE 2 NE
NORWALK SWG PL
HONEY CREEK BASIN
NORWALK 5 SE
TIFFIN
TIFFIN (H.C.)
FINDLAY SWG PL
FINDLAY FAA AP
PLYMOUTH 2 WSW
SYCAMORE (H.C.)
SANDUSKY RIVER BASIN
PHENECIE (H.C.)
LAKE ERIE BASIN
UPPER SANDUSKY
UPPER SANDUSKY WW
BUCYRUS
ASHLAND 2 SW
MANSFIELD WSO
CHARLES MILL LAKE
GALION WW
MANSFIELD 5 W
OHIO RIVER BASIN
SCALE
0
10
20
MILES
0
10
20
KILOMETERS
H.C.: STATION MAINTAINED BY WATER QUALITY LABORATORY AT HEIDELBERG COLLEGE

Figure 3.1 NWS and Heidelberg College meteorologic stations in and around Honey Creek Basin, Ohio.

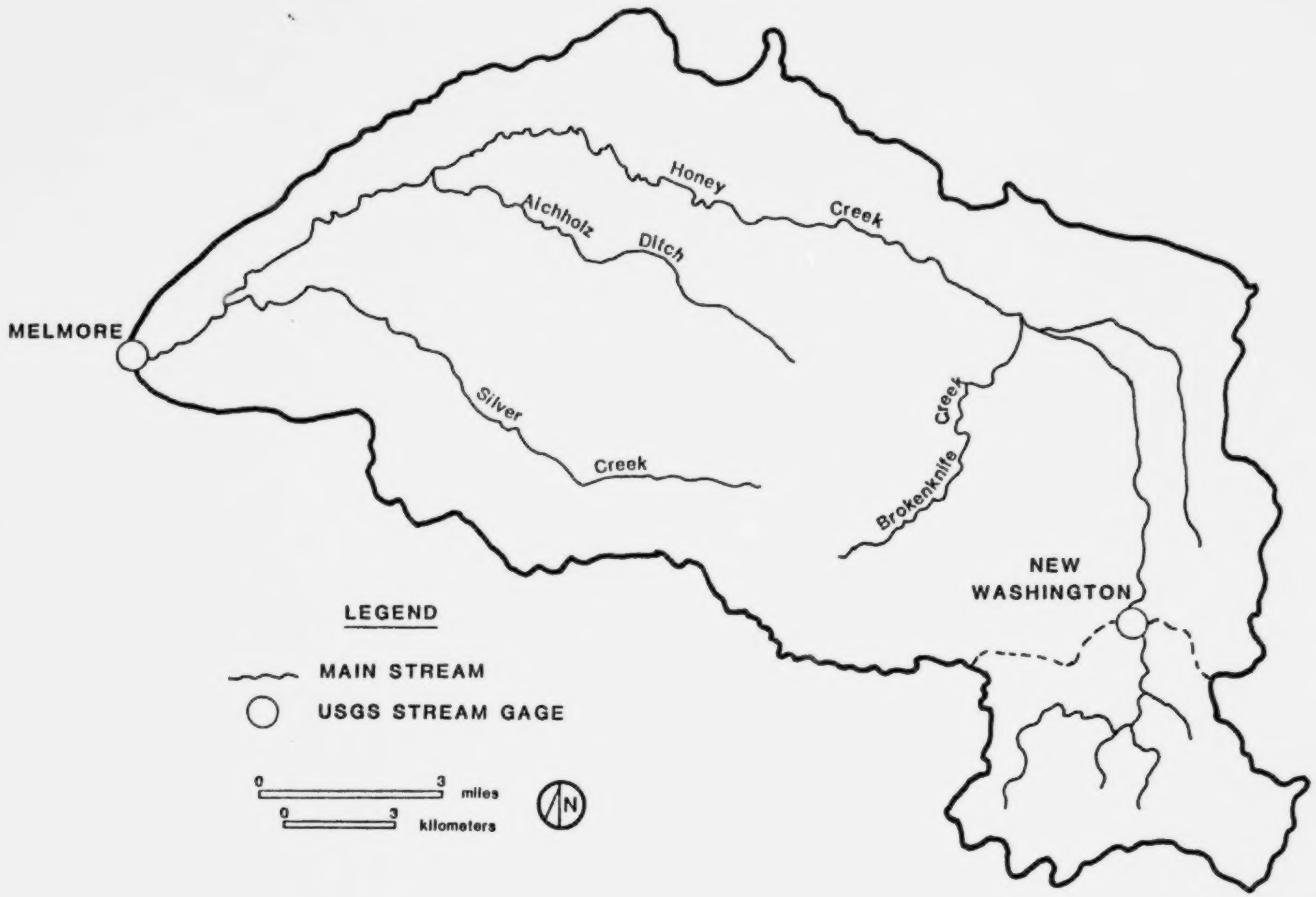

MELMORE
Honey
Creek
Alchholz
Ditch
Silver
Creek
Brokenknife
Creek
NEW
WASHINGTON
LEGEND
MAIN STREAM
USGS STREAM GAGE
0
3
miles
0
3
kilometers
N

Figure 3.2 USGS streamflow gages in the Honey Creek Basin.

TABLE 3.2 USGS STREAMFLOW GAGES IN THE HONEY CREEK BASIN

Station No.	Location	Drainage Area		Period of Record	Quality of Record
		Sq. km	(sq. mi.)		
4197020	Honey Creek near New Washington, OH	44	(17)	June 1979-present	Poor
4197100	Honey Creek at Melmore, OH	392.3	(151.5)	1961-present	Fair

and cubic feet per second) and maximum and minimum instantaneous streamflow (in cubic feet per second) are determined.

The Water Quality Laboratory at Heidelberg College recorded suspended sediment concentrations at Melmore from January 1976 to September 1982. The time series has a variable time step ranging from as frequently as every three hours to a gap of 62 days; typically, concentrations were recorded at least once a day. Suspended sediment concentrations during this period range from 0 to 9648 ppm.

Land surface gross erosion estimates are 7.8 MT/ha-yr (3.5 tons/ac-yr) for cropland, 8.1 MT/ha-yr (3.6 tons/ac-yr) for pastureland, and 5.6 MT/ha-yr (2.5 tons/ac-yr) for forest land (U.S. Dept. of Agriculture, 1982).

Water temperature data is periodically collected at several USGS stations in the Sandusky River Basin. A partial list of these gages is given in Table 3.3 along with their drainage areas and periods of record. Water temperatures were measured at intervals ranging from one to four months. Measured water temperatures at these gages range from 0.3 deg. C (32.5 deg. F) to 29 deg. C (84 deg. F).

3.3 SELECTION OF DATA FOR MODELING

The longest continuous period for which meterologic and streamflow data are available is February 1976 through October 1981. Data for this period were selected for the Honey Creek simulation.

TABLE 3.3 USGS STATIONS RECORDING WATER TEMPERATURE IN THE SANDUSKY RIVER BASIN

Location	Drainage Area Sq. km (sq. mi.)	Period of Record (Water Years)
Honey Creek at Melmore, OH	392 (151.5)	1976-7
Sandusky River at Fremont, OH	3015 (1164)	1951-6 1978-82
Sandusky River at Upper Sandusky, OH	772 (298)	1969-80
Tymochtee Creek at Crawford, OH	593 (229)	1968-77

3.3.1 Precipitation

Monthly and annual precipitation volumes from the Heidelberg College data are substantially lower than volumes recorded at surrounding NWS stations. The lower volumes can be attributed to discontinued data collection during winter months, gage malfunctions (e.g., dead batteries) noted on field sheets provided by Heidelberg College, and missing records during storm events. Given these possible sources of error, the surrounding NWS gage network was selected as the primary precipitation data source for the simulation.

The 30-year mean annual precipitation volumes recorded at the three NWS stations closest to the Honey Creek Basin are 88.85 cm (34.98 in.) at Bucyrus, 89.28 cm (35.15 in.) at Tiffin, and 93.90 cm (36.97 in.) at Plymouth 2 WSW (U.S. Weather Bureau, 1980). Using an approximation of the Thiessen method applied to surrounding NWS gages, a weighted average of the daily records at Tiffin (2/3 weight) and Bucyrus (1/3 weight) was selected to represent precipitation over the entire watershed. These stations were chosen based on their proximity to the basin, the similarity of their long-term mean annual volumes with those of surrounding NWS gages, and the completeness of their records. The daily storm event volumes were then distributed to hourly volumes using either the Heidelberg College hourly record at Tiffin or the NWS hourly record at Tiffin.

For some storm events, precipitation volumes at other surrounding NWS gages (Upper Sandusky, Plymouth 2 WSW, Findlay FAA AP, Galion Water Works, Mansfield 5 W, Mansfield WSO AP, and Norwalk Sewage Plant) show significant deviations with volumes determined by weighted averaging of the NWS Tiffin and Bucyrus gages. Such deviations are often associated with summer thunderstorm events typically characterized by convection cells of only 10 km (6.2 mi.) in diameter. The precipitation volumes for these events were revised based on review of records from all surrounding NWS gages and the "farmers' network" gages. Particular emphasis was placed on the NWS Upper Sandusky gage. The daily volumes were distributed to hourly volumes as described above. The dates of the revised events are listed in Table 3.4 for the entire simulation period.

3.3.2 Evaporation

Pan evaporation data is only available for April through October at the four weather stations near the Honey Creek Basin. The two NWS stations closest to the Honey Creek Basin which record pan evaporation are the Charles Mill Lake Weather Station and the Hoytville 2 NE Weather Station (approximately 53 km) southeast and 76 km (47 mi.) west of the center of the watershed, respectively). The Class A pan evaporation values recorded at the Hoytville 2 NE Station are consistently 80% greater than those recorded at the Charles Mill Lake Station. Local physiography at the two stations appears to account for the difference. The Hoytville 2 NE Weather Station is situated on flat terrain while the Charles Mill Lake Station is located next to a lake and flanked on the west by 300-foot hills which presumably reduce wind speeds. Since the Honey Creek Basin is relatively flat, the Hoytville 2 NE gage was selected to represent non-winter (April-October) pan evaporation.

Pan evaporation data for the winter months (November-March) were synthesized using long-term average evaporation data for Ohio (U.S. Dept. of Commerce, 1968) and the results of an

TABLE 3.4 DATES OF REVISED STORM EVENT VOLUMES BASED ON SURROUNDING NWS GAGES AND "FARMERS' NETWORK" GAGES

1976	1977	1978
Jan 13	Mar 18	Jan 26
Feb 17	Mar 22	Apr 20
Feb 21	Apr 2	May 17-18
Mar 6	Apr 21	May 13
Apr 24-25	May 4	Jun 13
May 18	Jun 6	Jun 26
May 30-Jun 2	Jun 9	Aug 3
Jun 25	Jun 17	Aug 7
Jun 29	Jul 1	Aug 10
Aug 7-8	Jul 22	Oct 1
Sep 17	Sep 10	Oct 26
Oct 31	Sep 16-19	
	Oct 1	

1979	1980	1981
Jun 10-11	Mar 8	Feb 19
Jun 20-22*	May 11-15	Apr 29
Jun 29	May 21	May 11-12
Jul 9-10	Jun 2-3	May 28
Jul 23-29	Jun 26	Jun 5 *
Aug 1-31**	Jul 28-29	Jun 8-10*

(continued)

(Table 3.4 continued)

Sep 1-3	Aug 8-9	Jun 13*
	Aug 16	Jul 3-4
	Aug 20	Jul 26-27
	Aug 31	Aug 11
		Aug 16
		Aug 28-Sep 4**
		Sep 27

* Volumes revised based on "farmer' network" data collected by Water Quality Laboratory at Heidelberg College.

**Daily data from NWS Tiffin gage not available for August 1979; daily record from NWS Upper Sandusky gage used.

evapotranspiration lysimeter test conducted during winter months at the Coshocton Agricultural Research Station (approximately 113 km (70 mi.) eastsoutheast of the Honey Creek Basin) (Cahill et al., 1979).

The pan evaporation data were adjusted to represent potential evapotranspiration using a pan coefficient of 0.75 (U.S. Dept. of Commerce, 1968).

3.3.3 Streamflow

The streamflow record from the USGS gage at Melmore was selected for comparison with simulated flow results. The Melmore gage was chosen for its larger drainage area, so as to be more consistent with the other watersheds simulated in this study. The USGS gage near New Washington was unsuitable for use in the simulation because it is missing almost 3 1/2 years of data for the 6-year simulation period. Furthermore, the quality of its record is characterized by the USGS as "poor".

3.3.4 Sediment

The land surface erosion estimates (U.S. Dept. of Agriculture, 1982) were used for comparison with simulated annual sediment washoff loads from the various land use types. The suspended sediment concentration data collected by the Water Quality Laboratory at Heidelberg College from February 1976 to October 1981 were used for comparison with simulated instream concentrations. Comparisons were made in the form of sediment concentration frequency curves.

3.3.5 Water Temperature

Water temperature data collected at the USGS Melmore gage were used for the simulation years of 1976 and 1977. Temperatures measured at the USGS Fremont gage on the Sandusky River were used for the remainder of the simulation period (1978 - October 1981). The measured values were used as monthly values; values for intermediate months were interpolated from the measured data.

3.3.6 Snow Simulation Data

Snow is an important component of the hydrologic cycle in the Honey Creek Basin. Four additional time series were required to simulate the accumulation and melting of snow: air temperature, wind speed, solar radiation, and dewpoint temperature.

3.3.6.1 Air Temperature--

Long-term climatological data indicate only small variations in maximum and minimum air temperature across the Honey Creek Basin (U.S. Dept. of Commerce, 1968). The small size, east-west orientation, and flat terrain of the basin also suggest that air temperature will be adequately represented by one gage record. Records of daily maximum and minimum air temperatures are available from two NWS gages near the Honey Creek Basin: Tiffin and Plymouth 2 WSW. The Tiffin gage, which has a more complete record over the simulation period, was selected to represent air temperature over the entire watershed.

The daily maximum and minimun air temperatures were converted to hourly values by using a stand-alone program that creates a diurnal temperature fluctuation based on long-term monthly averages of diurnal temperature variation.

3.3.6.2. Wind Speed--

Wind data, measured in miles per day at an elevation of 15-23 cm (6-9 in.) above a class A evaporation pan, are collected at the NWS Hoytville 2 NE and Charles Mill Lake Stations for the non-winter months (April-October). Wind levels at the Hoytville 2 NE Station are an average of 40% greater than those at the Charles Mill Lake Station. As with the evaporation data, the flat terrain which characterized the Honey Creek Basin is best represented by the topography at the Hoytville 2 NE gage. Furthermore, since wind speed is one of several factors that affects the rate of evaporation, the Hoytville 2 NE data was selected for both time series.

Wind data for the winter months (November-March) are collected at the Mansfield Lahm Municipal Airport, located approximately 32 km (20 mi.) southeast of the Honey Creek Basin. Winter wind data for the Honey Creek Basin were generated by using a power law profile to modify the airport wind speeds measured at a 10 m (33 ft.) elevation to represent ground level wind speeds at 0.67 m (2.2 ft), the height of wind measurements taken over class A evaporation pans. A power factor of 1/7 was selected, for it has been found applicable for a wide range of conditions in the 0 to 10 m (0-33 ft) layer (Linsley, 1975).

3.3.6.3 Solar Radiation--

The daily solar radiation record from the Wooster Agricultural Research Station was selected to represent solar radiation over the entire Honey Creek Basin. Personnel at the Wooster Station suggested that all solar radiation values be increased by 10% to reflect field calibration of the data. As with the air temperature time series, a stand-alone program distributed the daily solar radiation values to hourly values to represent diurnal variation.

3.3.6.4 Dewpoint Temperature--

Previous studies have shown similarity between average daily dewpoint temperature and daily minimum air temperature. The daily minimum air temperature record from the NWS gage at Tiffin was selected to represent dewpoint temperature in the Honey Creek Basin since no dewpoint temperature record collected within the basin is available.

3.4 QUALITY OF SELECTED DATA

The time series data used in the Honey Creek simulation are of good to fair quality. A complete hourly precipitation record was unavailable so daily records had to be disaggregated to hourly values based on hourly records at surrounding gages. This is a possible source of error for individual storm events but will give an adequate representation of precipitation over the basin for the 6-year simulation period.

The evaporation record is of good quality except for the synthesized winter data. However, since evaporation is generally reduced during the winter months, the impact of the synthesized data on the simulation should be minimal. The quality of the NWS Tiffin air temperature (and dewpoint temperature) record is very good with only 35 records missing for the 6-year simulation period. These missing records were filled in using the record from the NWS Bucyrus gage. Wind and solar radiation data are of good quality; a few missing records were filled in using data from surrounding stations.

The streamflow record from the Melmore gage is classified as fair by the USGS. The record is complete for the simulation period, February 1976 to October 1981.

The sediment concentration data are of good quality but have numerous gaps in the record. A frequency analysis of the data will produce lower than actual concentration frequencies due to the missing data. However, the data can be used for general comparison between simulated and observed instream concentrations.

Water temperature data are required by HSPF to simulate the sand transport capability of a river using the Toffaleti method. Small variations in temperature have little impact on this simulation and, furthermore, sand transport is of little importance in this study compared to transport of silt and clay. Thus, the USGS data selected for most of the simulation period from the nearby Sandusky River gage are sufficient for the modeling purposes of this study.

3.5 DATA TIME SERIES SUMMARY

The weighted average of records from two NWS rain gages (Tiffin: 2/3, Bucyrus: 1/3) near the Honey Creek Basin was selected to represent precipitation over the entire watershed.

The pan evaporation record at the NWS Hoytville 2 NE Station was chosen for the entire basin and was multiplied by a pan coefficient of 0.75 to represent potential evapotranspiration. The daily maximum and minimum air temperature record from the NWS Tiffin Station was selected to represent air temperature and dewpoint temperature for the basin. Wind data from the NWS Hoytville 2 NE Station and solar radiation data from the Wooster Agricultural Research Station were chosen for the simulation. The streamflow record from the USGS gage at Melmore was selected for comparison of simulated and observed streamflow. Water temperature data collected by the USGS at Melmore and in the Sandusky River at Fremont were used to simulate sand transport. Suspended sediment concentration data collected by the Water Quality Laboratory at Heidelberg College were used for comparison with simulated instream concentrations.

SECTION 4

WATERSHED SEGMENTATION FOR HSPF APPLICATION

4.1 PERVIOUS LAND SEGMENTATION

The segmentation of the watershed into separate pervious land segments (PLSs) for simulation by HSPF is based on an evaluation of the following factors:

1. meteorological patterns
2. soils characteristics
3. land use

4.1.1 Meteorologic Patterns

As shown in the previous section, there is neither significant meteorologic variability nor adequate database to warrant the use of more than one time series per meteorologic data type to represent conditions in the Honey Creek Basin. The precipitation records from two NWS stations, located northwest and south of the watershed, were weighted based on the approximate areal percentage of the basin that each gage covered. The sum of the two weighted records was applied to the entire basin, resulting in only one meteorologic segment. Thus, there may be small errors for individual storm events but the weighted average of the two gages adequately represents the precipitation in the basin over the 6-year simulation period.

4.1.2 Soils Characteristics

Soils can have a large influence on basin discharge behavior because their properties determine the rates of infiltration, percolation, and interflow, which in turn affect the timing and quantity of runoff. Variability of soils characteristics within a watershed will produce different hydrologic responses from different parts of the basin. Individual pervious land segments should be established to represent these different characteristics.

The soils in the Honey Creek Basin are relatively homogeneous across the watershed. Typically they consist of poorly drained silt loams on slopes of 0 to 2%. Small variations in soils characteristics do not significantly impact the hydrologic response from one area of the basin to another so no additional segmentation was required.

4.1.3 Land Use

Different land uses modify the hydrologic response of an area chiefly by the impacts of the different vegetation regimes. The vegetation of an area affects the infiltration, surface detention, interception, and evapotranspiration processes of the hydrologic cycle represented by HSPF.

Table 2.2 provides a listing of land use types in the Honey Creek Basin along with the areas of each type and the percentages of each type with respect to total watershed area. These various land uses can be categorized into three major vegetation types:

1. crops (59.7% of watershed)
2. forest (10.4% of watershed)
3. pasture (and other uses) (29.9% of watershed)

The two major crops are corn and soybeans. Corn occupies 25.3% of the watershed and soybeans are grown on the remaining cropland, 34.4% of the basin (Cahill et al., 1979; Stuckey, 1983; Smith, 1983). These two crops were each represented by separate pervious land segments.

Forested land occupies 10.4% of the basin. A third pervious land segment was used to account for the different evapotranspiration and drainage characteristics of this land use. A fourth pervious land segment representing pastureland, smaller acreages of other crops, and all other land uses (wetlands, surface waters, urban areas) accounted for the remaining watershed area.

4.1.4 Final Pervious Land Segmentation

Meteorologic patterns are fairly uniform across the Honey Creek Basin so only one meteorologic segment was required. Homogeneity of soils across the watershed required no additional segmentation based on soils characteristics. Variations in land use were represented by four pervious land segments - corn, soybeans, forest, and pasture (and other land uses). Table 4.1 lists the segments and the areas of each contributing to the streamflow at the USGS gage at Melmore.

4.2 IMPERVIOUS LAND SEGMENTATION

Because of the low percentage of impervious land area in the basin, no impervious land segments were used in the simulation.

4.3 CHANNEL SEGMENTATION AND NETWORK

Segmentation of a river for simulation by HSPF requires consideration of channel characteristics such as cross-section shape and river bed slope and roughness, entry points of major tributaries, and locations of stream gages used for comparison of simulated and observed flow and sediment.

4.3.1 Channel Characteristics

The main stem of Honey Creek from the upstream drainage divide to the outlet at the USGS stream gage at Melmore is approximately 58 km (36 mi.) long. The average slope of the main stem is 0.08%. The headwaters of Honey Creek originate in a large swampy area. Downstream from this area, numerous slightly meandering, incised channels come together to form the main stem of Honey Creek. Portions of the upper stem have been channelized. The lower half of Honey Creek meanders along the northern side of a broad floodplain.

TABLE 4.1 PERVIOUS LAND SEGMENTS AND AREAS CONTRIBUTING TO STREAMFLOW AT USGS GAGE AT MELMORE

PERLND	Land Use	Area Sq. km	(sq. mi.)
1	Corn	99.4	(38.4)
2	Soybeans	134.7	(52.0)
3	Pasture (and other	117. 1	(45.2)
4	Forest	40.9	(15.8)
Total		392.1	(151.4)

Channel cross-sectional area gradually increases downstream and there are no abrupt changes in river bed slope.

4.3.2 FTABLE Definition

The hydraulic characteristics of each reach must be specified in an FTABLE for use in the HSPF input sequence. FTABLEs specify values for surface area, reach volume, and discharge for a series of selected average depths of water in the reach; intermediate values are interpolated.

A stand-alone computer program was used to generate the FTABLES based on Manning's formula and channel characteristics. This program requires inputs of reach length, upstream and downstream bed elevations, channel bottom and bankfull widths, channel height, floodplain slope, and roughness (i.e., Manning's n) values for both the channel and the floodplain.

The main stem of Honey Creek was divided into two segments, such that each reach drained approximately equal areas. A third reach segment represented a major tributary, Silver Creek. Reach lengths and bed elevations, used for calculating bed slopes, and floodplain slopes were determined from USGS topographic quadrangles. Channel dimensions and Manning's n values were estimated from cross-section profiles measured by the Soil Conservation Service and from observations made during field visits.

4.3.3 Reach Network Summary

The reach segmentation described above consists of three reaches, two of which are connected in series to represent the main stem. For the purposes of simulation, it is assumed that the third reach joins the main stem at the outlet of the basin. As can be seen in Figure 4.1, this is not entirely accurate but is sufficient for modeling purposes. Figure 4.1 shows the three reaches and their contributing land areas. The characteristics of each reach are listed in Table 4.2 and the corresponding FTABLES are shown in Table 4.3.

4.4 CONNECTIVITY OF LAND SEGMENTS AND STREAM REACHES

The four land uses represented by pervious land segments in the Honey Creek simulation are uniformly distributed throughout the basin. Thus, a portion of each land segment contributes to all three reaches. The areas of the land segments contributing to the individual reaches are listed in Table 4.4.

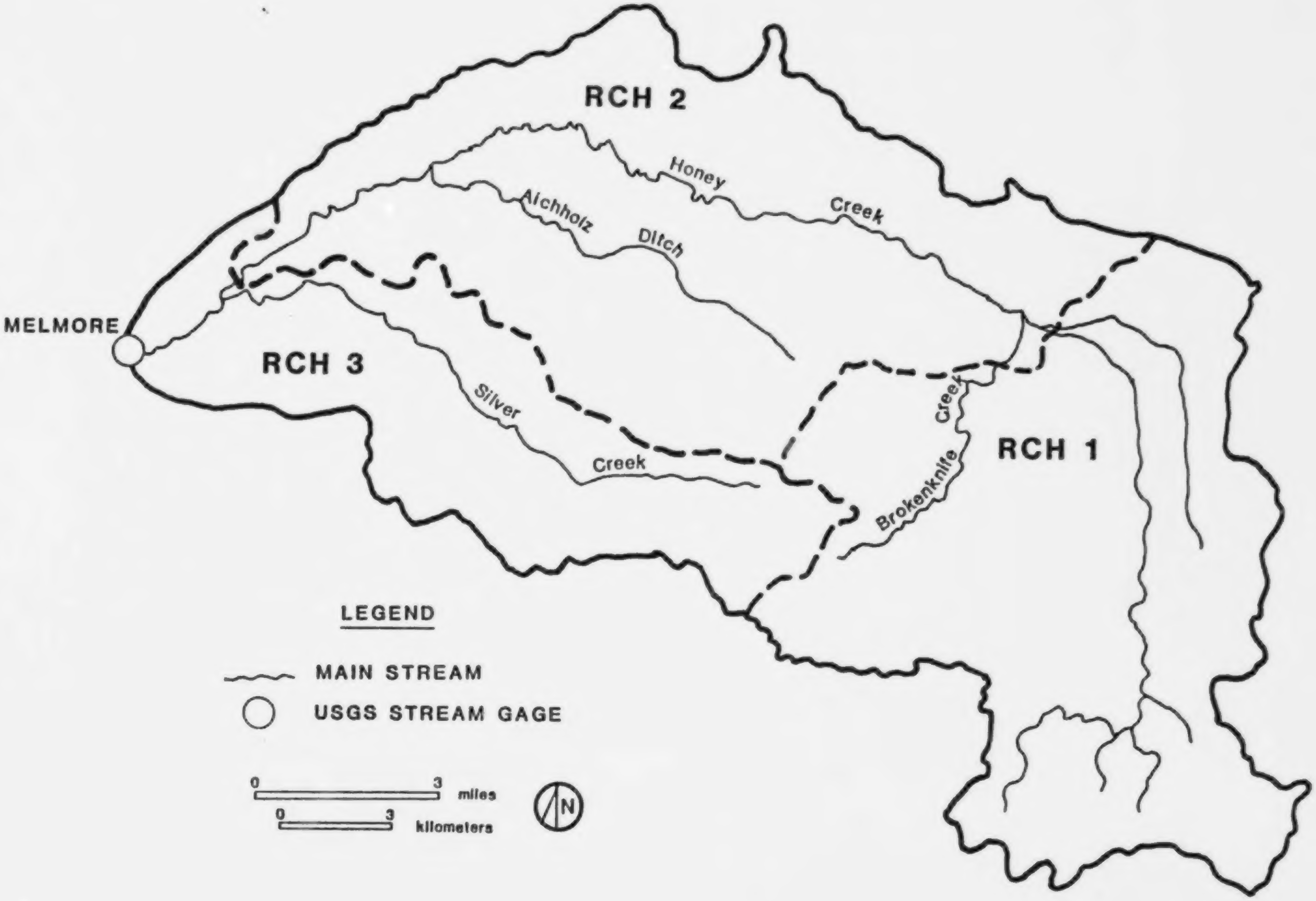

RCH 2
Honey
Creek
Aichholz
Ditch
MELMORE
RCH 3
Silver
Creek
Creek
Brokenknife
RCH 1
LEGEND
MAIN STREAM
USGS STREAM GAGE
0
3
miles
0
3
kilometers
N

Figure 4.1 River segmentation for the Honey Creek Basin.

TABLE 4.2 REACH CHARACTERISTICS OF THE HONEY CREEK SIMULATION NETWORK

Reach	Length km (mi.)	Average Slope %	Bottom Width m (ft)	Bankfull Width m (ft)	Channel Height m (ft)	Flood-plain Slope %	Channel n	Flood-plain n
1	9.7 (6.0)	0.104	10.7 (35)	22.9 (75)	2.7 (9)	0.7	.045	.10
2	31.2 (19.4)	0.068	15.2 (50)	36.6 (120)	2.4 (8)	2.0	.045	.10
3	26.9 (16.7)	0.113	9.1 (30)	21.3 (70)	2.7 (9)	6.5	.045	.10

TABLE 4.3 FTABLES USED FOR THE HONEY CREEK REACH SIMULATION

```
FTABLES
  FTABLE      1
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .750    27.879   20.0000   23.4173     620.1
     1.500    30.303   41.8182   75.3986     402.7
     2.250    32.727   65.4545  150.5622     315.6
     3.000    35.152   90.9091  247.3875     266.8
     3.750    37.576  118.1818  365.3691     234.8
     4.500    40.000  147.2727  504.4606     211.9
     6.000    44.848  210.9091  846.9139     180.8
     7.500    49.697  281.8182 1277.7649     160.1
     9.000    54.545  360.0000 1801.0647     145.1
    12.000   677.922 1458.7014 4173.8203     253.7
    15.000  1301.299 4427.533210438.7970     307.9
    18.000  1924.676 9266.490222730.7380     296.0
  END FTABLE  1

  FTABLE      2
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .667   131.293   82.9562   22.4405    2683.8
     1.333   145.010  175.0573   72.8242    1745.2
     2.000   158.727  276.3030  146.5487    1368.8
     2.667   172.444  386.6935  242.5971    1157.2
     3.333   186.162  506.2290  360.8674    1018.4
     4.000   199.879  634.9091  501.6557     918.8
     5.333   227.313  919.7037  852.9149     782.9
     6.667   254.747 1241.0774 1301.5166     692.3
     8.000   282.182 1599.0300 1853.3518     626.4
    10.667   909.253 3187.6094 3692.8247     626.7
    13.333  1536.323 6448.3770 6665.1563     702.4
    16.000  2163.39411381.330011182.8420     738.9
  END FTABLE  2

  FTABLE      3
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .750    67.475   48.0758   20.9887    1662.9
     1.500    74.222  101.2121   67.7750    1084.2
     2.250    80.970  159.4091  135.7884     852.3
     3.000    87.717  222.6667  223.9014     722.0
     3.750    94.465  290.9849  331.8790     636.5
     4.500   101.212  364.3636  459.8796     575.2
     6.000   114.707  526.3030  777.5243     491.4
     7.500   128.202  708.4850 1180.8853     435.6
     9.000   141.697  910.9091 1674.7942     394.9
    12.000   328.550 1616.2798 3262.2178     359.7
    15.000   515.403 2882.2100 5603.6152     373.4
    18.000   702.256 4708.6992 8910.1191     383.7
  END FTABLE  3
END FTABLES
```

TABLE 4.4 AREAS OF PERVIOUS LAND SEGMENTS CONTRIBUTING TO STREAM REACHES

		Contributing Areas sq. km (sq. mi.)			
PLS	Land Use	RCH 1	RCH 2	RCH 3	Total
1	Corn	39.6 (15.3)	40.1 (15.5)	19.7 (7.6)	99.4 (38.4)
2	Soy-beans	53.6 (20.7)	54.4 (21.0)	26.7 (10.3)	134.7 (52.0)
3	Pasture (and other uses)	50.5 (19.5)	45.1 (17.4)	21.5 (8.3)	117.1 (45.2)
4	Forest	13.5 (5.2)	18.1 (7.0)	9.3 (3.6)	40.9 (15.8)
Total		157.2 (60.7)	157.7 (60.9)	77.2 (29.8)	392.1 151.4)

SECTION 5

HSPF CALIBRATION AND VERIFICATION

5.1 OVERVIEW AND SPECIAL PROBLEMS

The calibration process is performed to adjust model parameters so that simulated and observed system outputs agree within some measure of acceptance. Typically, this is accomplished in several stages. The logical order is to calibrate land segment hydrologic processes followed by stream hydraulics in order to properly simulate watershed hydrologic response. Simulated watershed outputs and changes in storage are compared whenever possible to observed values. Next, sediment washoff from the land surface followed by instream sediment process calibration is performed. After the system is calibrated the simulation results are verified by simulating the outputs for a different period of time and comparing them to observed outputs.

The Honey Creek Watershed calibration was performed in the above manner and followed the general procedures discussed in the HSPF Application Guide (Donigian et al., 1984). The results of the hydrologic calibration were evaluated using three main methods: comparison of simulated and observed annual and monthly runoff volumes; comparison of simulated and observed flow frequency curves; and comparison of simulated and observed hydrographs. Following these comparisons several statistical tests, described below, were performed to further evaluate the calibration results. Likewise for the sediment calibration, several comparisons between simulated results and estimated or observed values were made to evaluate the simulation of sediment processes. These included: simulated sediment washoff loads and gross erosion estimates for the various land use types; simulated and observed instream sediment concentrations at the outlet of the basin; simulated and observed frequency curves of the instream concentrations; and the simulated and observed stability of the channel (i.e., degradation or aggradation).

One special problem encountered in the Honey Creek simulation was the lack of any meteorologic data collected within the watershed. All data time series used were from gages located 8-97 km (5-60 mi.) outside of the basin boundary. Consideration of localized rainfall was not possible due to the use of two rain gages located outside of the basin boundary which were combined into one precipitation time series. Thus, runoff produced from localized rainfall not recorded at the gages could not be simulated. Conversely, localized rainfall recorded at one or both of the gages and applied to the entire basin would result in simulated runoff greater than actual runoff. The weighting of the two gages based on approximate areal coverage of the basin minimized these errors and produced an acceptable hydrologic simulation.

Another problem was the brevity of the simulation period (5 years, 9 months) due to the length of the observed streamflow record. This made simulation of the watershed over a wide range of conditions impossible. The longest period for which

1976 through October 1981. The period of January 1979 to October 1981 was chosen for the calibration and the remaining years, February 1976 to December 1978, were used for verification. This choice was made based on the greater range of annual precipitation amounts occurring during the later years of the simulation period. Proper hydrologic calibration requires a period of record that demonstrates a range of soil moisture and runoff conditions (Donigian et al., 1984).

5.2 HYDROLOGIC/HYDRAULIC CALIBRATION AND VERIFICATION

The initial selection of hydrologic and hydraulic parameters for the Honey Creek simulation was based on guidelines given in the user's manual for EPA's Agricultural Runoff Management (ARM) Model (Donigian and Davis, 1978); information obtained from the Water Quality Laboratory at Heidelberg College in Tiffin, Ohio; Soil Conservation Service soil surveys for Seneca and Crawford Counties, Ohio; previous experience with HSPF applications; and other miscellaneous sources.

A 2-hour timestep was chosen for the simulation interval. Comparisons of model results from other watershed simulations in this study for 1-hr. and 2-hr. time steps showed that the minor differences could be eliminated with slight adjustments to parameters.

Simulated and observed annual runoff for the USGS gage at Melmore are listed in Table 5.1 for both the calibration and verification periods. Generally, simulated and observed values within 10% of each other is considered a very good simulation. Overall, simulated runoff volumes for the calibration period were very good on a long-term basis and good to very good for individual years. For the verification

TABLE 5.1 SUMMARY OF SIMULATED AND OBSERVED RUNOFF VOLUMES (cm) AT THE USGS GAGE AT MELMORE

Calibration

Year	SIM	OBS	Difference as a % of OBS
1979	47.6	45.3	+5
1980	25.6	22.6	+13
1981*	34.9	35.1	-1
Total	108.1	103.0	+5

Verification

Year	SIM	OBS	Difference as a % of OBS
1976**	13.5	16.7	-19
1977	21.6	28.9	-25
1978	23.7	28.7	-17
Total	58.8	74.3	-21

SIM = Simulated
OBS = Observed
* January - October only (10 months)
**February - December only (11 months)

period, simulated runoff volumes were fair for both the entire period and individual years.

Total runoff for the calibration period was oversimulated by only 5% of the observed value. Individual annual amounts were undersimulated by 1% and oversimulated by 5 and 13%. Total runoff for the verification period was undersimulated by 21% of the observed value. Annual runoff amounts for individual years were undersimulated by 17 to 25%.

Table 5.2 shows a water balance for the four land use types for one representative year for each of the calibration and verification periods. The years shown have precipitation amounts close to the long-term average annual rainfall amount. The balances show that subsurface flow is the primary contributor to runoff and that there is more runoff from agricultural land than from forested land. This was due to the effects of subsurface tile drains on runoff.

To further evaluate the simulation of runoff volumes, scattergrams of simulated vs. observed monthly flows were plotted. These are shown for both calibration and verification periods in Figure 5.1 for the USGS gage at Melmore. In addition, correlation analyses were performed on the mean monthly flow data as well as for mean daily flows and 3-day average flows. Correlation coefficient (i.e.,R-squared) values from these analyses are listed in Table 5.3. A correlation coefficient greater than 0.80 generally indicates good to very good calibration results. Coefficients for mean monthly flows are greater than 0.81 for both the calibration and verification periods. A substantial increase in the correlation coefficients from the mean daily flows to the 3-day average flows is an indication that simulated flow magnitudes are fairly accurate but the timing is off by one or two days, particularly for peak flows. These results indicate

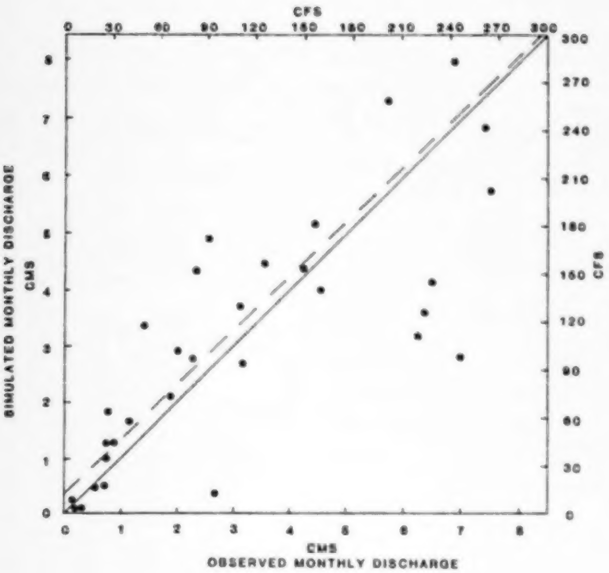
TABLE 5.2 TYPICAL ANNUAL WATER BALANCE (CALIBRATION AND VERIFICATION) FOR THE FOUR SIMULATED LAND USE TYPES

Calibration - 1980

cm	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Pasture	PLS 4 Forest
Precipitation	90.6	90.6	90.6	88.9
Evapotranspiration	69.1	68.2	69.5	73.4
Runoff	25.3	25.8	26.3	22.1
Surface	5.5	5.6	2.7	1.1
Interflow	7.7	7.7	7.3	6.9
Ground water	12.1	12.5	16.3	14.1

Verification - 1978

cm	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Peanuts	PLS 4 Forest
Precipitation	91.8	91.8	91.8	88.8
Evapotranspiration	66.2	65.6	67.4	72.8
Runoff	25.2	25.8	23.6	18.2
Surface	3.7	4.1	1.4	1.3
Interflow	10.1	10.7	7.3	6.4
Ground water	11.4	11.0	14.9	10.5

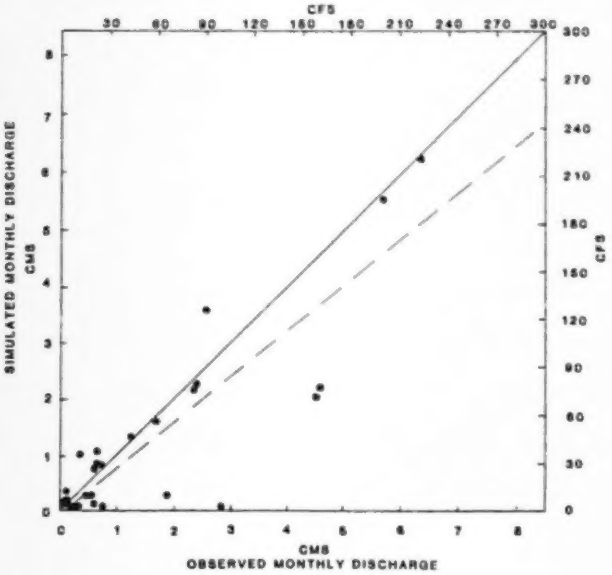


CALIBRATION

R SQUARED = .813

Y INTERCEPT = 0.34 CMS

SLOPE = .970



VERIFICATION

R SQUARED = .807

Y INTERCEPT = - 0.08 CMS

SLOPE = .814

Figure 5.1 Mean monthly flow scattergrams at the USGS gage at Melmore.

TABLE 5.3 CORRELATION COEFFICIENTS (R-SQUARED) FROM REGRESSION ANALYSES OF STREAMFLOW AT THE USGS GAGE AT MELMORE

Calibration

	R-Squared
Mean daily flows	.606
3-day average flows	.754
Mean monthly flows	.813

Verification

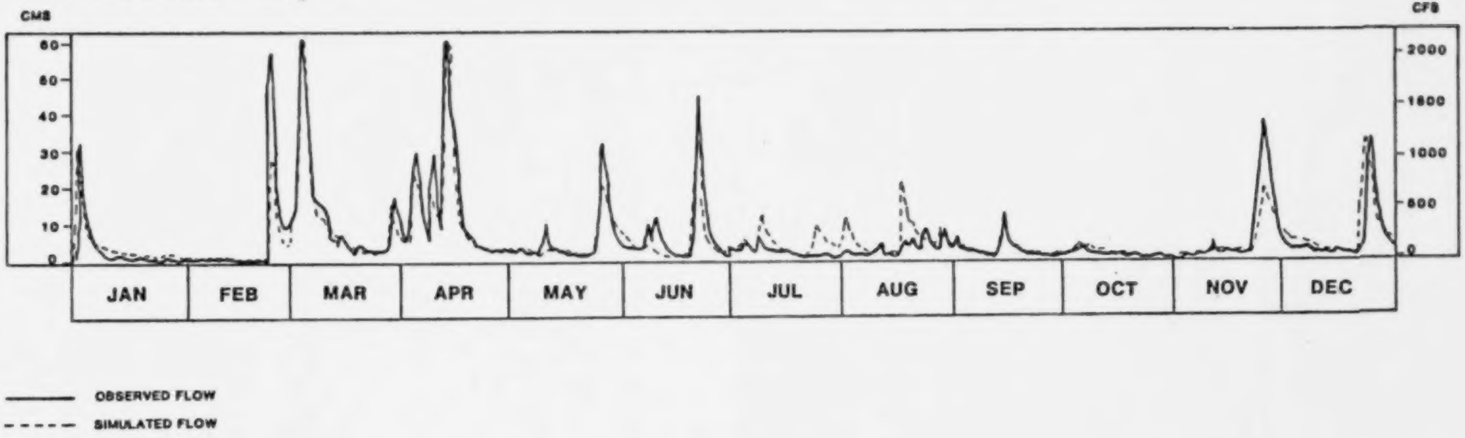
	R-Squared
Mean daily flows	.724
3-day average flows	.794
Mean monthly flows	.907

good calibration of monthly runoff volumes for the entire simulation period.

Figure 5.2 shows the hydrographs for one year for the calibration and verification periods for the USGS gage at Melmore. Generally, the simulated and observed hydrographs are matched fairly well. Several of the simulation problems discussed previously are also evident from the hydrographs. For example, several simulated peaks in July and August of 1979 illustrate the effect of localized rainfall. Apparently, precipitation was recorded at one or both of the rain gages which was not representative of rainfall over the entire basin. The result is simulated runoff considerably greater than that which was observed. The opposite problem is illustrated by a runoff event in January and February of 1978. Here the gages did not record rainfall which fell on a portion of the basin, resulting in undersimulated runoff. Timing discrepancies between simulated and observed events can also be examined on the hydrographs. A simulated peak in December of 1979 occurs 2 days before the observed peak, even though the magnitude of the event was accurately simulated. This situation may be an indication of inaccuracies in reach simulation (e.g., unrepresentative FTABLES), especially if a trend of early or late simulated peaks is apparent, or differences in the timing of rainfall recorded at the gage versus when it fell on the watershed. However, most simulated peaks over the entire Honey Creek simulation period occur on the same day as observed peaks, indicating a good simulation of both runoff and reach hydraulics.

The primary emphasis of the calibration was the accurate simulation of flow frequencies over the 3-year period. Good simulation of flow frequencies is a better indicator of the model's ability to represent watershed hydrologic response than exact simulation of individual observed events. Figure

CALIBRATION - 1979



VERIFICATION - 1978

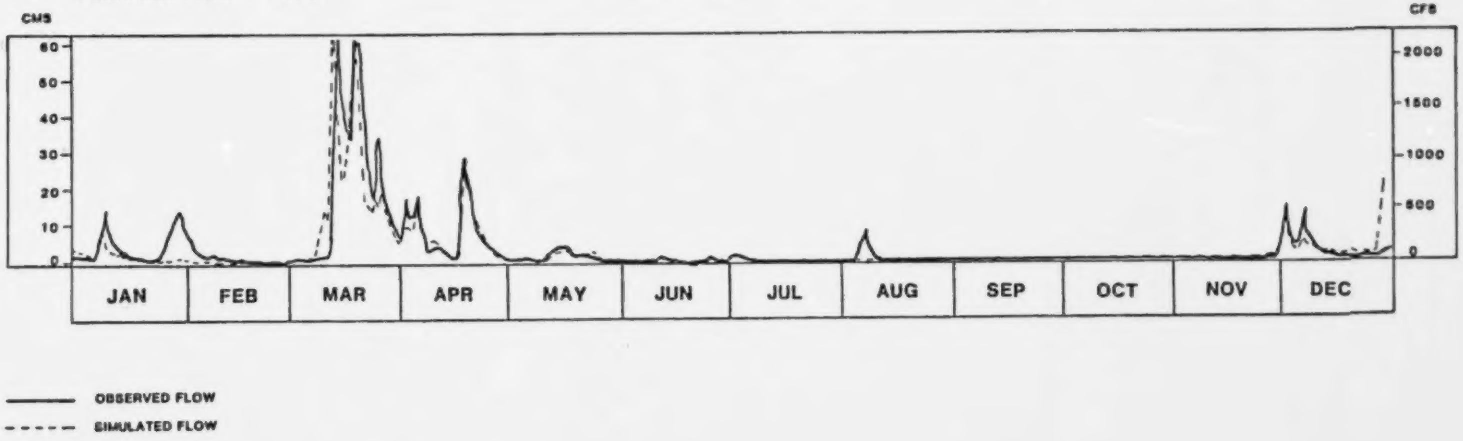


Figure 5.2 Calibration and verification hydrographs at the USGS gage at Melmore.

5.3 shows the simulated and observed flow frequencies at the USGS gage at Melmore for the calibration period. Figure 5.4 shows the same information for the verification period. Intermediate flows are slightly undersimulated and high and low flows are slightly oversimulated for the calibration period. For the verification period high and low flows are slightly undersimulated and intermediate flows are simulated very well. The simulated and observed frequencies for the entire simulation period are matched quite well, indicating that the calibration of flow frequencies was successful.

In addition to visual observation, the goodness of fit of the flow frequency curves was quantitatively evaluated using a statistical hypothesis testing method, the Kolmogorov-Smirnov (K-S) test of model simulations (Haan, 1977). Though not a rigorous test, the K-S test provides an indication of overall agreement between two cumulative distributions and has been used in past modeling studies (Hartigan et al., 1982; Young and Alward, 1983). A basic assumption of the K-S test is that the data are independent of each other within a sample. In the case of daily streamflow, a value on any given day is strongly related to previous values. Autocorrelation analyses of each simulated and observed flow time series were conducted to determine the interval, k, such that every k-th observation out of the entire time series was considered a random sample. The results of the autocorrelation analyses indicated that, for the sample to be independent within the 95% confidence limit, the following intervals, k (in days), should be used:

Calibration		Verification	
simulated	observed	simulated	observed
15	17	40	38

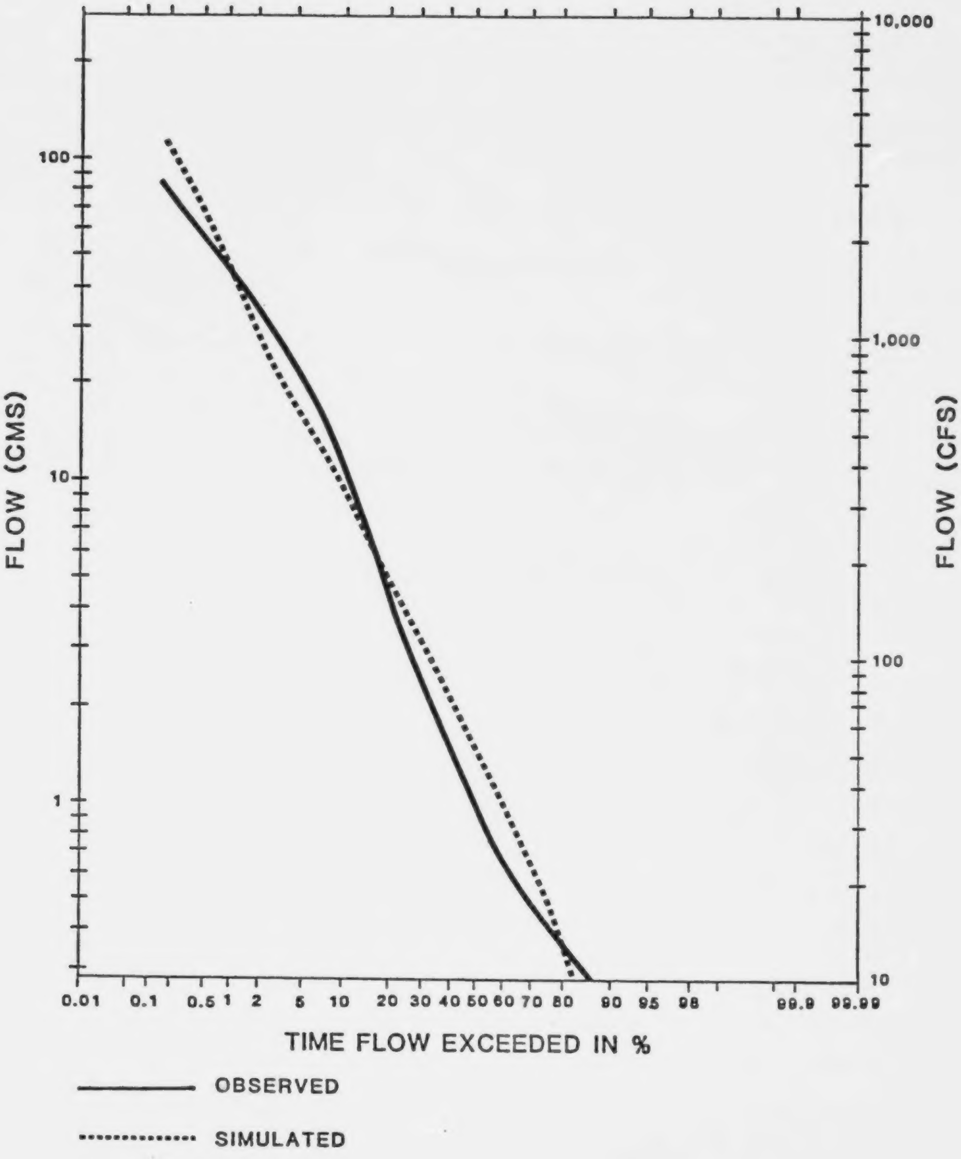


Figure 5.3 Flow frequencies at the USGS gage at Melmore for the calibration period.

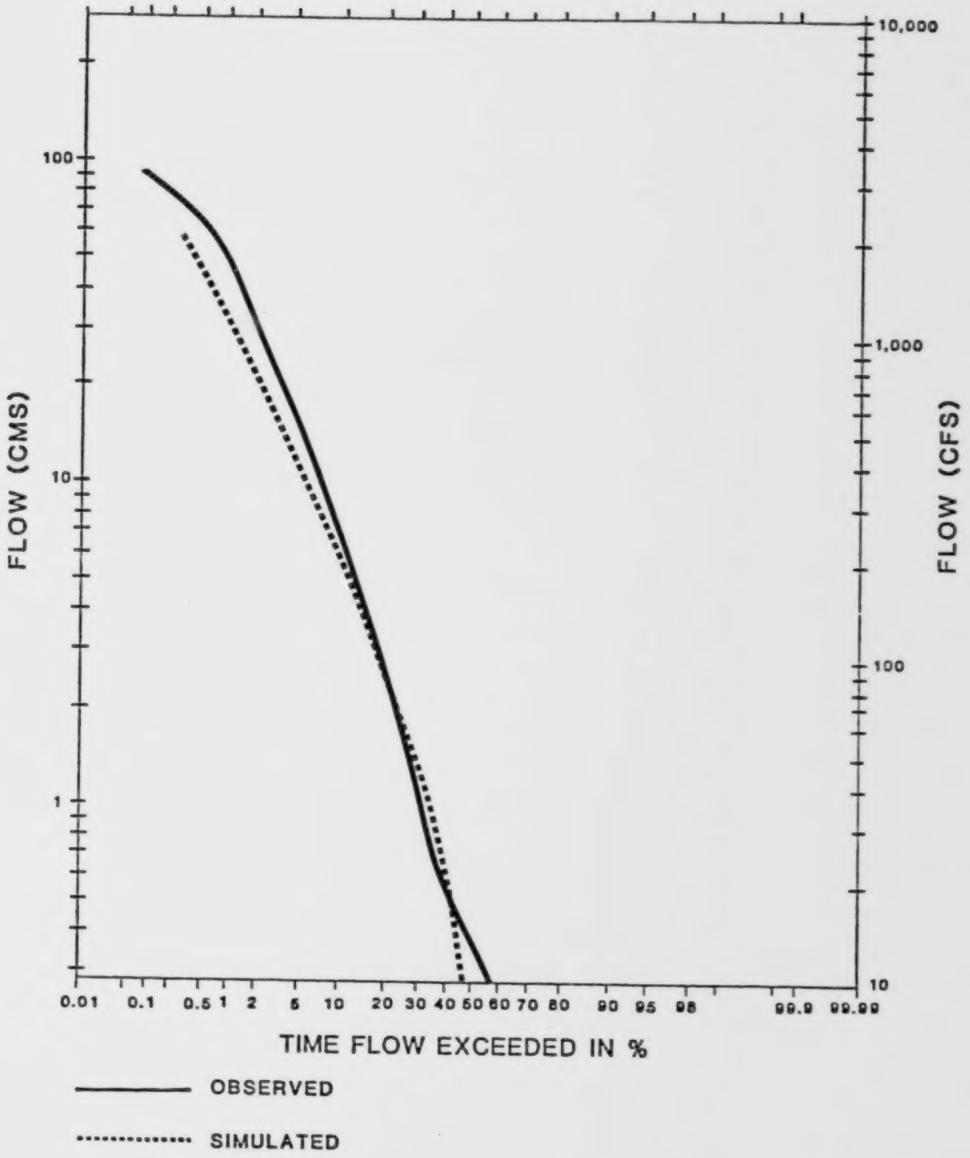


Figure 5.4 Flow frequencies at the USGS gage at Melmore for the verification period.

The difference between the cumulative probability densities of the simulated and observed flows should not exceed a critical value, with a given significance level, in order to pass the test. The K-S test results are shown in Table 5.4 for the USGS gage at Melmore for the calibration and verification periods. Streamflow simulation passed the K-S test at the 10% significance level for both the calibration and verification periods. These results are a further confirmation of the validity of the simulation of the Honey Creek Basin.

The final hydrologic parameters for the four pervious land segments are listed in Table 5.5. The annual ranges of monthly parameters are shown in the table. All parameters are given in English units.

5.3 SEDIMENT CALIBRATION AND VERIFICATION

The soil erosion and sediment transport calibration was performed in a manner similar to the hydrologic calibration. First, overland sediment transport was simulated to provide edge-of-stream loadings. Gross erosion estimates for the various land uses (PLSs) in the Honey Creek area were compared to the simulated values in order to achieve reasonable erosion rates. Second, instream sediment simulation was performed by adjusting channel sediment parameters to produce the best fit between simulated and observed daily suspended sediment concentrations at the USGS gage at Melmore.

TABLE 5.4 RESULTS OF K-S TESTS OF STREAMFLOW SIMULATION AT THE USGS GAGE AT MELMORE

Calibration

Significance Level	D	D max
10%	0.22	
1%	0.29	0.20
0.1%	0.34	

Verification

Significance Level	D	D max
10%	0.33	
1%	0.44	0.12
0.1%	0.53	

TABLE 5.5 FINAL HSPF HYDROLOGIC PARAMETERS OF THE HONEY CREEK SIMULATION (English Units)*

PERLND Module - Section PWATER

Parameter	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Pasture	PLS 4 Forest
LZSN	7.0	7.0	7.5	8.0
INFILT**	0.04-0.07	0.04-0.07	0.07	0.09
LSUR	350.	350.	320.	320.
SLSUR	0.02	0.02	0.022	0.03
KVARY	3.0	3.0	3.0	4.0
AGWRC	0.97	0.97	0.97	0.985
INFEXP	2.0	2.0	2.0	2.0
INFILD	2.0	2.0	2.0	2.0
DEEPFR	0.15	0.15	0.15	0.15
BASETP	0.05	0.05	0.05	0.1
AGWETP	0.07	0.07	0.07	0.3
CEPSC**	0.02-0.18	0.02-0.18	0.02-0.18	0.06-0.20
UZSN**	0.3-0.8	0.3-0.8	0.7	1.0
NSUR**	0.25-0.30	0.25-0.30	0.25	0.35
INTFW	1.3	1.3	1.5	2.0
IRC	0.2	0.2	0.4	0.5
LZETP	0.3-0.7	0.3-0.6	0.3-0.6	0.4-0.9

* See HSPF User Manual (Johanson et al., 1984) for unit definitions.

** Range of monthly values used.

5.3.1 Edge-of-Stream Sediment Loadings

Estimated erosion losses for the Honey Creek area are 7.8 MT/ha-yr (3.5 tons/ac-yr) for corn and soybeans, 8.1 MT/ha-yr (3.6 tons/ac-yr) for pastureland, and 5.6 MT/ha-yr (2.5 tons/ac-yr) for forest land (U.S. Dept. of Agriculture, 1982). Table 5.6 lists the simulated annual sediment washoff values for the four pervious land segments for two years each of the calibration and verification periods. Note that a 6-year period is a very short record for developing estimates for comparison to average annual washoff loads. Erosion loads are extremely variable year to year. Loads estimated by the Universal Soil Loss Equation (USLE) are for a 22-year average when parameters are estimated as per guidelines.

Also, note that the estimates are average annual gross erosion loads while simulated loads represent edge-of-stream loadings. Vegetation surrounding cropland and pastureland and riparian vegetation typically act as settling areas preventing substantial quantities of eroded sediment from reaching stream channels. Thus, the simulated edge-of-stream loadings are expected to be less than the gross erosion estimates for the various land uses. The values shown in Table 5.6 represent delivery ratios of 30% to 40% for corn and soybeans. i.e., only 30% to 40% of gross erosion actually reaches the stream channel. These are reasonable delivery values for this watershed.

5.3.2 Instream Sediment Simulation

Simulated suspended sediment concentrations were compared to data collected by the Water Quality Laboratory at Heidelberg

TABLE 5.6 SIMULATED ANNUAL SEDIMENT LOADINGS FROM THE FOUR PERVIOUS LAND SEGMENTS

Calibration

Year	Sediment Washoff (MT/ha) PLS 1 Corn	PLS 2 Soybeans	PLS 3 Pasture	PLS 4 Forest
1979	1.75	1.80	0.47	0.14
1980	1.44	1.39	0.50	0.13
Average	1.60	1.60	0.49	0.14

Verification

Year	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Pasture	PLS 4 Forest
1977	1.16	1.21	0.04	0
1978	0.41	0.46	0.18	0.13
Average	0.79	0.84	0.11	0.06

College. The observed data have a variable time step ranging from as frequently as every three hours to a gap of 62 days; typically concentrations were recorded at least once a day. If multiple samples were taken on one day (typically during major runoff events), these were averaged to obtain a mean daily concentration. Most of the data gaps of one week or longer duration occurred during low flow periods in 1979 and 1980.

Simulated and observed sediment concentration frequency curves for the USGS gage at Melmore are shown in Figure 5.5 for the calibration and verification periods. For the calibration period, the simulated and observed curves are matched quite well. High and low concentrations are slightly oversimulated while intermediate concentrations are slightly undersimulated. For the verification period, high and intermediate concentrations are somewhat oversimulated and low flows are slightly undersimulated.

Observations in the Honey Creek Basin indicate the channels are degrading (Baker, 1984). Simulation results also show a slow degradation. Table 5.7 shows annual sediment mass balances for two years each for the calibration and verification periods. Note that there is a net scour from the channel system for three of the four years shown. Simulated changes in bed depth show small amounts of scour. Simulated bed distributions of sand, silt, and clay fractions show small changes, reflecting scour of fine particles. Long-term mean annual suspended sediment yields for basins in north central and northwestern Ohio range from 0.20 to 1.27 MT/ha-yr (Anttila and Tobin, 1978). Simulated annual yields fall within or near this range.

The final set of sediment parameters are listed in Table 5.8 for both the land surface (PERLND Module - Section SEDMNT) and

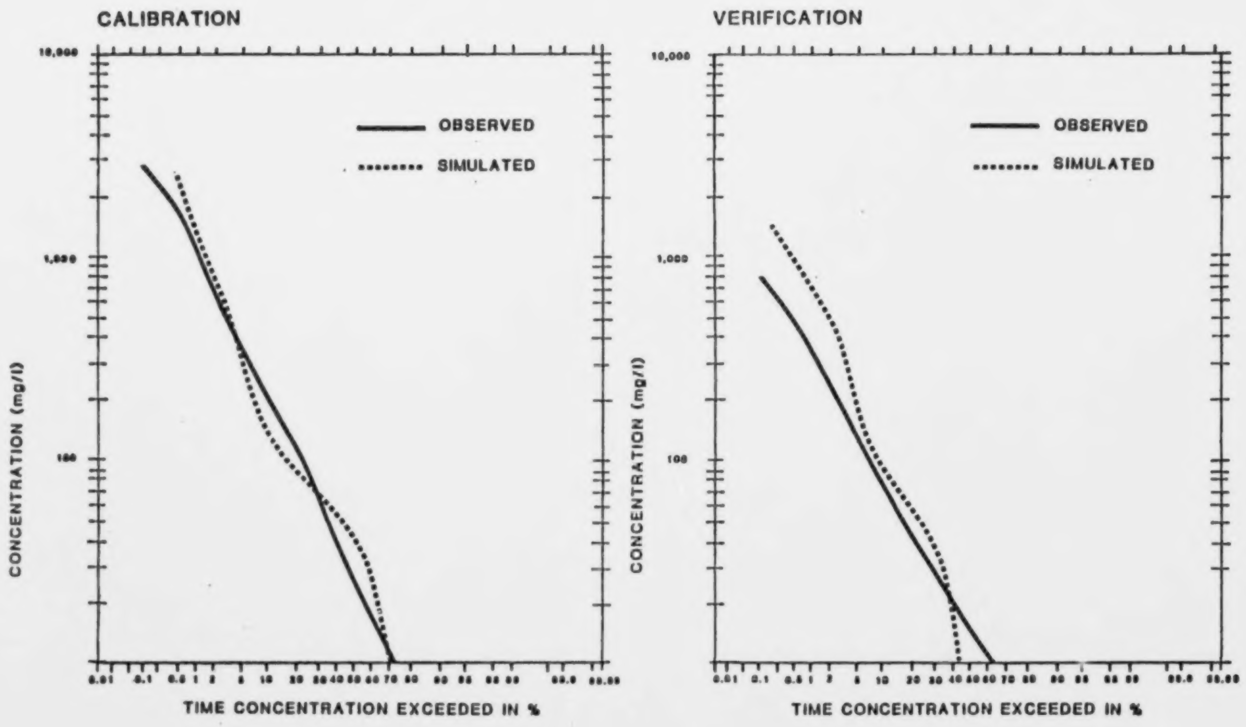


Figure 5.5 Instream sediment concentration frequency curves for the calibration and verification periods.

TABLE 5.7 SIMULATED ANNUAL SEDIMENT MASS BALANCES

Calibration

	Simulated Sediment Loads (MT/ha)		
Year	Total Load at Melmore	Total Load from Land Surface*	Load from Channel System
1979	1.55	1.21	+0.34
1980	1.14	1.01	+0.13

Verification

Year	Total Load at Melmore	Total Load from Land Surface*	Load from Channel System
1977	0.65	0.72	-0.07
1978	0.83	0.34	+0.49

* Total Load from land Surface = (25.3% of basin in corn * sed. load from corn) + (34.4% of basin in soybeans * sed. load from soybeans) + (29.9%) of basin in pasture * sed. load from pasture) + (10.4%) of basin in forest * sed. load from forest).

TABLE 5.8 FINAL HSPF SEDIMENT PARAMETERS OF THE HONEY CREEK SIMULATION (English Units)*

	PERLND Module - Section PWATER			
Parameter	PLS 1 Corn	PLS 2 Soybeans	PLS 3 Pasture	PLS 4 Forest
KRER	0.40	0.40	0.32	0.28
JRER	2.0	2.0	2.2	2.2
AFFIX	0.03	0.03	0.003	0.003
COVER**	0.20-0.70	0.20-0.65	0.60-0.80	0.80-0.90
KSER	2.8	2.8	2.3	2.0
JSER	1.7	1.7	2.0	2.0
KGER	0.0	0.0	0.0	0.0
JGER	1.0	1.0	1.0	1.0
DETS**	0.5-1.0	0.5 -1.0	0.1	0.05

	RCHRES Module - Section SEDTRN		
Parameter	Sand	Silt	Clay
D	0.02	0.00063	0.000055
W	2.3	0.0025	0.000022
RHO (g/cm)	2.65	2.2	2.0
TAUCD	-	0.015	0.010
TAUCS	-	0.035,0.045	0.025,0.035
M	-	0.002	0.002

---

* See HSPF User Manual (Johanson et al., 1984) for units.

** Range of monthly values used.

the reach system (RCHRES Module - Section SEDTRN). The annual ranges of monthly parameters are shown in the table. All parameters are given in English units except where noted.

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APPENDIX J

Iowa River, Iowa

Watershed Data, Segmentation, and HSPF Calibration/Verification Report

ABSTRACT

The EPA Hydrological Simulation Program - FORTRAN (HSPF) was applied to the Iowa River Basin in central Iowa as part of the development of a methodology to estimate pesticide runoff and resulting instream concentrations from agricultural cropland in various regions of the United States. The Iowa River Basin was chosen as representative of watersheds in the Western Cornbelt region. HSPF was calibrated and verified for hydrology, hydraulics, sediment erosion, and instream sediment transport as a basis for performing sensitivity analyses on key pesticide chemical parameters.

This report describes the watershed data available for simulation, the sedimentation plan for dividing the study area into land and channel segments, and the results of the calibration and verification efforts. In general, this study produced a fair hydrologic calibration and verification and a fair to good sediment simulation. The sediment simulation results could not be completely calibrated and verified due to lack of sufficient observed sediment data for a rigorous model application. The model results for both hydrology and sediment were considered quite acceptable for the purposes of this study.

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SECTION 1

INTRODUCTION AND EXECUTIVE SUMMARY

The application of HSPF to the Iowa River Basin was undertaken as part of the parent study, described in the body of this report, to develop procedures for estimating the likely magnitude and variability of instream pesticide concentrations and pesticide runoff from cropland in selected agricultural regions of the U.S. The overall approach was to evaluate the characteristics of "representative" agricultural watersheds within each region, perform sensitivity analyses using HSPF for a range of selected chemical properties, and transform the model results into a series of curves for estimating (1) the frequency and duration of pesticide concentrations at a watershed outlet, and (2) pesticide runoff from the associated cropland; to use the curves the only information needed is chemical properties and the chemical application rate. To provide a sound basis for the methodology HSPF was applied to actual watersheds within each agricultural region as a demonstration of its ability to simulate chemical transport processes on agricultural watersheds throughout the country. The Iowa River Basin was selected as the HSPF application site within the Western Cornbelt Region.

1.1 STUDY OBJECTIVES

Within the framework of the study described above, the objectives of the HSPF application to the Iowa River Basin were as follows:

a. demonstrate the ability of HSPF to model the hydrologic, hydraulic, sediment erosion, and sediment transport behavior of an agricultural watershed characteristic of the Western Cornbelt Region;

b. estimate selected model parameters, which are usually evaluated through calibration, as a basis for determining representative parameter values for the region.

Pesticide simulation was not performed as part of this application due to the lack of observed pesticide data for comparison with model results and lack of adequate project resources; however, previous studies with HSPF (Donigian et al., 1983) and with predecessor models (Donigian et al., 1977) have sufficiently confirmed the pesticide capabilities of HSPF for the purposes of this project.

The Iowa River Basin was selected as an application site because of its location in the Western Cornbelt Region, its agricultural land, an earlier HSPF application, and the availability of a reasonably adequate data base for model application. The Iowa River Basin was the subject of a previous demonstration application of HSPF to model water quality and the effects of agricultural best management practices (Imhoff et al., 1983). To meet the goals of this earlier project only a limited number of hydrologic and sediment calibration runs were performed, leaving considerable room for improvement. The work performed on the Iowa River Basin for the current project uses the same data base developed for the 1983 study and is a refinement of the results presented in the 1983 report.

The pesticide assessment methodology developed in the parent study provides a screening-level type analysis with order-of-magnitude accuracy in its predictions. Consequently, a greater degree of latitude was possible in the needed accuracy of the HSPF calibration than would have been allowable for more detailed and demanding planning, design, or watershed management purposes. Also, resource limitations required restrictions on the level of calibration. However, the model results are consistent with and well suited to the overall objectives and framework of this study.

1.2 REPORT CONTENT

The remainder of this introductory section provides an overall summary of the results of the HSPF application to the Iowa River Basin, followed by conclusions and recommendations for future improvements in the simulation. The body of this appendix begins with the watershed and study area descriptions in Section 2, and the discussion of available data for modeling in Section 3. Section 4 describes the HSPF representation of the watershed through segmentation of the land area, based on meteorologic, edaphic, and land use characteristics, and segmentation of the stream channel. The approach and results of the calibration/verification exercise is then described in Section 5.

1.3 SUMMARY OF RESULTS

The Iowa River Basin study area, located in central Iowa, is comprised of the 7236 sq. km (2794 sq. mi.) drainage area above Marengo, Iowa. Between 65 and 85% of each county which contributes land to the basin is cropland, with the majority of the cropland being either soybeans or corn.

Preliminary hydrologic and sediment calibration of the study area was performed in an earlier HSPF demonstration project (Imhoff et al., 1983). The purpose of the current work was to refine the calibration efforts reported in that study.

Variability in meteorologic patterns necessitated the division of the study area into three meteorologic segment groups, and each segment group was further divided into three land use segments (beans, corn, and pasture/other). Segment group boundaries were refined based on rainfall patterns, topography, soils and drainage characteristics. To model instream flow hydraulics and sediment transport processes, the 300 km main channel was divided into 13 reaches based on locations of major tributary inflows, channel slope discontinuities, and USGS streamflow gage sites.

Initial calibrations were performed on two small test watersheds within the basin in order to develop representative parameter set values for local segments. Following successful hydrologic simulation results on these smaller basins, the input parameter sets were applied to appropriate segments of the study area. Further calibrations were then made to refine parameters as they applied to the segments of the entire study basin. Kinematic wave routing was performed on the calibrated runoff volumes, allowing direct comparison with observed streamflow records at three USGS gages.

Detachment and removal of sediment from the basin lands were simulated based on input rainfall, simulation of overland flow, and input model parameter values describing the soil characteristics and land surface conditions. Sediment delivery from the nine land segments to the stream channel, as modeled by HSPF, was compared to available estimates of gross erosion rates and edge-of-stream delivery rates developed for other Iowa lands. When reasonable agreement was achieved, simulation of instream sediment transport processes was performed based on inflow of sediment from upstream reaches, loadings from tributary land segments, and exchange of sediments between the bed and suspension.

Results of the hydrologic/hydraulic simulation were compared to observed streamflow at gages located at Rowan, Marshalltown, and Marengo. Problems stemming from use of unrepresentative rainfall records and deficiencies in modeling snowmelt made simulation of the observed hydrologic reponse of the basin a difficult task. Given that good representation of individual storm events could not be achieved using available rainfall records, the primary goal of the Iowa River simulation was faithful reproduction of observed flow frequencies. This goal was accomplished at the two downstream gages at Marshalltown and Marengo.

Overall, sediment simulation in the Iowa River Basin was quite successful within the constraints created by the flow simulation problems. Observed and simulated frequency curves for average daily sediment concentrations at Marengo compared favorably. Both land surface erosion rates and channel bed aggradation/degradation appeared reasonable for the 5-year simulation period.

1.4 CONCLUSIONS AND RECOMMENDATIONS

HSPF was used successfully to model hydrology and sediment in the Iowa River Basin. Although the hydrologic simulation was adequate for the purposes of this study, improvement of results would be desirable, particularly if the model were to be used for site-specific planning purposes. By far the greatest problem in the basin simulation was the inadequacy of the three selected rainfall records in representing the 7236 sq. km watershed. Given the consistently large variations in rainfall patterns, it is not likely that any three records could effectively represent the basin segments. Accurate representation would best be accomplished by weighting and combining a number of nearby stations to synthesize areal average records for each of the meteorologic segment groups. Improvement of rainfall representation should be the top priority in future simulation efforts.

As was the case in previous applications of HSPF to Iowa study watersheds, simulation of timing of snowmelt runoff was poor, making calibration of the spring runoff period a difficult task. More research, algorithm development, and data is needed to better represent the full spectrum of relevant processes.

The brevity of the simulation period (five years), coupled with the occurrence of record low-flow conditions, limited the number and nature of flow events available for the calibration effort, and hence development of accurate values for calibration parameters was hindered. Extension of the existing 5-year data base should be another top priority for future studies.

Extrapolation of hydrology and sediment parameter values from the nearly Four Mile Creek watershed was used extensively and successfully in this study. Use of parameter values from nearby or representative calibrated watersheds is an effective means of minimizing the amount of effort needed to calibrate a new watershed.

By adequately reproducing the observed runoff frequencies for the simulation period, it was possible to achieve an equally successful reproduction of observed sediment concentration frequencies. The HSPF simulation of both land surface erosion and channel bed aggradation/degradation appeared reasonable. However, more data on both facets of sediment transport are needed to verify the simulation results. For this study instream sediment parameters for critical shear stress of erosion, critical shear stress of deposition, and erodibility coefficient were assigned constant values throughout all 13 reaches. If supporting data were available, it would be useful to assign values for these parameters on a reach-specific basis. Nonetheless, the overall parameter set used for the sediment simulation did produce satisfactory results.

Having produced adequate hydrologic and sediment representation of the study area, the linking of chemical transport to these mechanisms should provide realistic forecasts of pesticide movement through similar basins.

SECTION 2

IOWA RIVER BASIN DESCRIPTION

2.1 LOCATION, SIZE, AND SURFACE PHYSIOGRAPHY

The Iowa River Basin headwaters originate in Hancock County, Iowa, and the river flows in a southeasterly direction to its confluence with the Mississippi River between Muscatine and Burlington, Iowa on the southeast border of the state (Figure 2.1). For the purposes of this study the streamflow gaging station at Marengo, Iowa, in Iowa County was selected as the downstream terminus, and the resulting drainage area is 7236 sq. km (2794 sq. mi.). South of Marengo, the river drains into Coralville Reservoir, which is a major recreational area for central Iowa, and then flows past Iowa City, for which it serves as a water supply source. The study basin is wholly contained in the state of Iowa, and 14 counties contribute to its drainage area.

The study area has three distinct topographical areas. The first area is the northern area of the of basin above Alden, where the topography is largely defined by the most recent periods of glaciation during the Wisconsin period. Due to the relative youth of this glacial deposit, the surface drainage

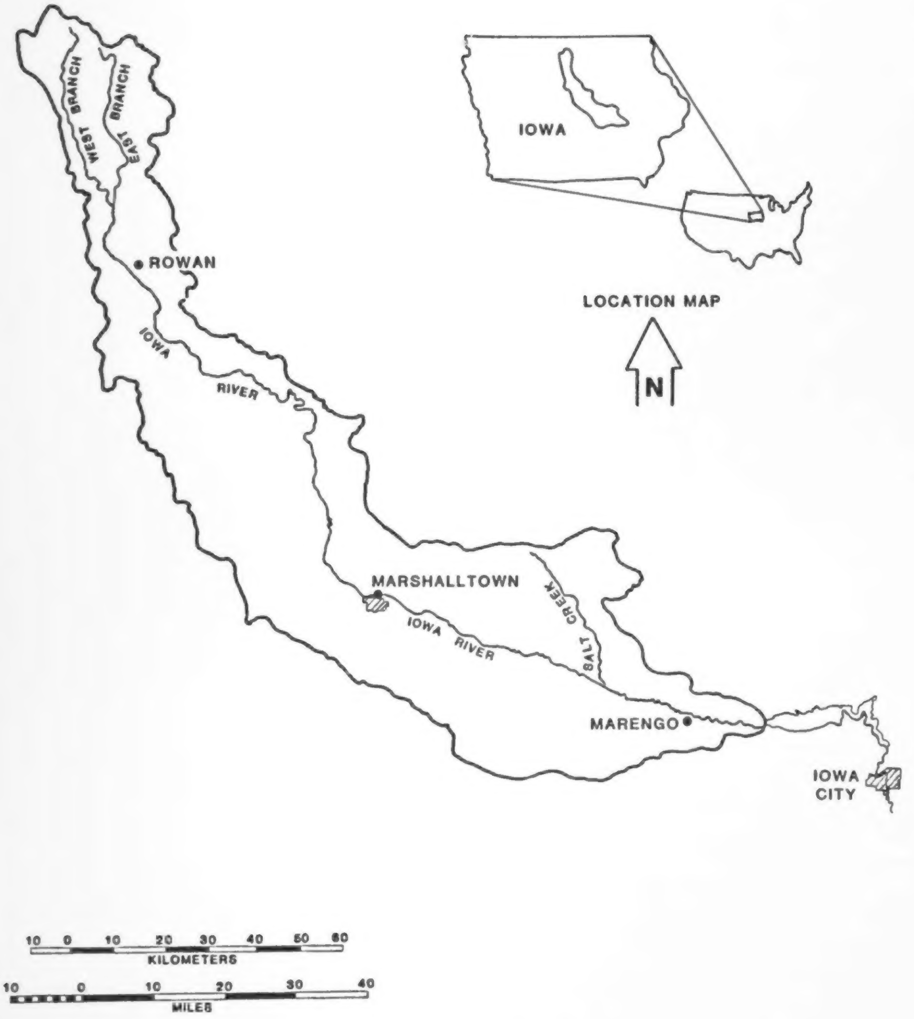

WEST BRANCH
EAST BRANCH
ROWAN
IOWA RIVER
MARSHALLTOWN
IOWA RIVER
SALT CREEK
MARENGO
IOWA CITY
IOWA
LOCATION MAP
N
10 0 10 20 30 40 50 60
KILOMETERS
10 0 10 20 30 40
MILES

Figure 2.1 Location of the Iowa River Basin.

pattern is poorly developed, and much of the topography is nearly level to gently undulating with occasional depressions, lakes, ponds, and sloughs. The lateral drainage system has been supplemented with artificial channels, but considerable ponding still may occur after periods of heavy rainfall (Iowa Dept. of Environmental Quality, 1977).

The second area, between Alden and Marshalltown, is more hilly terrain, but is still predominantly glacial deposits from the Wisconsin period. Drainage patterns in this central area are better defined than those of the northern area. Most of the basin south of Marshalltown is dominated by the older Kansan glacial drift. The Kansan drift plane has been deeply dissected along the major drainageways, but much of the original surface is preserved on the broad, flat divides. Natural drainage is well developed throughout the Kansan area. The table-like divides are drained by broad, shallow valleys which, as they approach the major streams, deepen into steep-walled ravines. Along the northern boundary of this lower region in parts of Grundy, Tama, and Benton Counties the erosional topography of the Kansan is considerably modified by dune-like accumulation of wind-blown material, or loess, usually found on the eastern slopes of the hills (Iowa Dept. of Environmental Quality, 1977).

2.2 CLIMATE

The following description of climatology is extracted in its entirety from the Supporting Document for Iowa Water Quality Management Plans (Iowa Dept. of Environmental Quality, 1976).

Iowa's climate, because of latitude and interior continental location, is characterized by marked seasonal variations.

During the six warm months of the year the prevailing moist, southerly flow from the Gulf of Mexico produces a summer rainfall maximum. The prevailing northwesterly flow of dry Canadian air in the winter causes this season to be cold and relatively dry. At intervals throughout the year, air masses from the Pacific Ocean moving across the western United States reach Iowa, producing comparatively mild and dry weather. The autumnal "Indian Summers" are a result of the dominance of these modified Pacific air masses. Hot, dry winds, originating in the desert southwest United States, occasionally sweep into Iowa during the summer producing unusually high temperatures and desicating crops.

The average annual temperatures for the Iowa River Basin range from 7.8 deg C (46 deg F) in the northern counties to 10 deg C (50 deg F) in the southeastern counties. In July, the hottest month, the average daily maximum is around 30.6 deg C (87 deg F) and the daily minima are mostly in the lower 60's. In January daily maxima range from -4.4 deg C (24 deg F) to 1.1 deg C (34 deg F), north to south, and the minima from -13.9 deg C (7 deg F) to -10 deg C (14 deg F).

The growing season for warm weather crops extends from mid-May to early October. The spring growing season suitable for hardy crops, lasts approximately six weeks and the autumn season about seven. The dormant season, averaging 19 weeks, extends from mid-November to late March. The crop growing season is limited by both spring and fall freezes in Iowa.

Mean annual precipitation for the basin varies from 76 cm (30 in.) in the north to 84 cm (33 in.) in the southeast. The cyclic annual pattern of Iowa precipitation varies from approximately 3 cm in February to nearly 13 cm during June, a direct consequence of the availability of the moisture and the proximity of the eastward moving storms. During winter the storm track is more often displaced well to the south of Iowa, migrating northward with heaviest rainfalls in May and June and diminishing during July as the storms track across Canada. A secondary, but lesser, rainfall maximum is associated with the southward movement of the prevailing storm track across Iowa in August or September.

On nearly half of all the days in the year a trace or more precipitation falls at all Iowa locations. The preponderance of rainfall days are with small precipitation amounts. Annually the thunderstorm days total about 40 days in the north and 50 days in the south. Mean annual snowfall ranges from 102 cm (40 in.) in the northernmost area of the basin to about 69 cm (27 in.) in the south. The season normally extends from October or November to April but measurable snow has fallen as late in the season as May 28, (1947) and as early as September 25 (1942). The average number of days with snow cover three cm or deeper per season varies from about 40 days along the southern border to around 90 in the northernmost counties. The average date of the first three cm (1 in.) snowfall varies from November 25 in the north to December 10 in the southeast.

Since Iowa is located under or near storm tracks all year, atmospheric pressure differences readily produce winds that occur almost all the time. At the level 6.1 m (20 ft.) above ground, average monthly wind speeds vary from 12.5 km/hr (7.8 mph) in August upward to 19.8 km/hr (12.4 mph) in April. Mean annual potential evapotranspiration for the Iowa River Basin varies from 64 cm (25 in.) in the north to 69 cm (27 in.) in the south.

2.3 SOILS AND GEOLOGY

Most of the Iowa River Basin is covered with prairie soil formed from glacial drift, an unconsolidated mixture of gravel and partly weathered rock fragments left by glaciers. Underlying the drift, at a considerable depth, are consolidated rocks that out-crop where the river has cut deep into the drift. The soil types of the Iowa River Basin may be generally grouped according to parent material into glacial drift soils and loess soils. The soils may also be grouped into soil associations which indicate areas within which a repeating pattern of soil types is found. The Clarion-Webster and Storden-Clarion-Webster soil associations, located in the headwaters of the Iowa River Basin are found on drift material deposited during the last substages of the Wisconsin ice advance. This area is in a youthful stage of development, and the land surface has undergone only minor alteration by erosion since retreat of the glaciers. Natural drainage is poor in much of the area. With proper drainage the soils of the late Wisconsin drift area are some of the most productive in Iowa. Natural fertility is good, and the mineral and organic matter content is high.

In the southern part of the basin most of the Kansan drifts are covered with a blanket of wind-deposited loess. This has given rise to four soil associations: Tama-Muscatine, Mahaska-Taintor, Fayette, and Clinton-Lindley. The loess found in this area is different from that in western Iowa in that the deposits are not as deep (1.5 to 4.5 m), and they are finer-particled and have much lower infiltration rates. Drainage is not a serious problem in the loess area, but erosion control measurements are needed on the more rolling topography. Figure 2.2 shows the boundary between the Wisconsin and the Kansan soil associations.

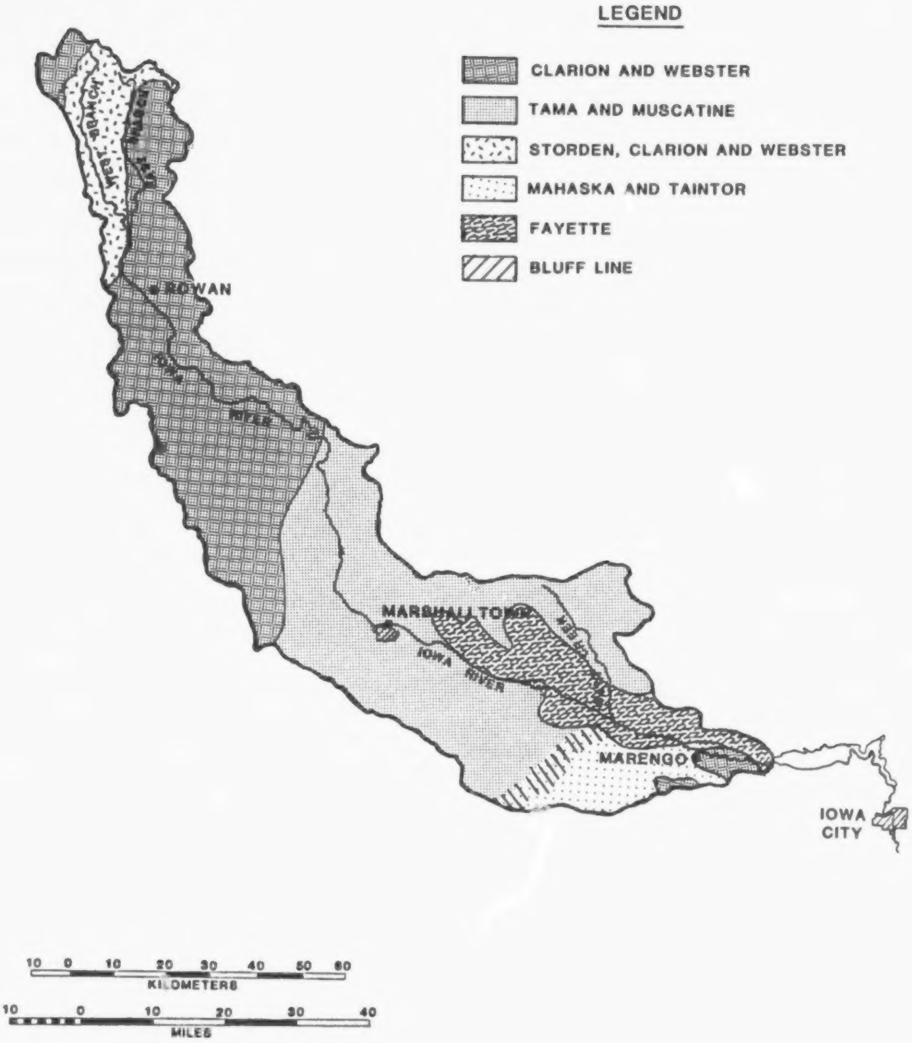

LEGEND
CLARION AND WEBSTER
TAMA AND MUSCATINE
STORDEN, CLARION AND WEBSTER
MAHASKA AND TAINTOR
FAYETTE
BLUFF LINE
WEST BRANCH
ROWAN
IOWA
RIVER
MARSHALLTOWN
IOWA RIVER
MARENGO
IOWA CITY
10 0 10 20 30 40 50 60
KILOMETERS
10 0 10 20 30 40
MILES

Figure 2.2 Major soil groups in the Iowa River Basin.

2.4 LAND USES AND MANAGEMENT

For the Iowa River Basin, between 65 and 85% of each county which contributes land to the basin is cropland, with the majority of the cropland being either corn or soybeans. Of all other land uses, only grassland comprises more than 10% of the area's total usage. While detailed land use figures have not been developed separately for the Iowa River Basin, combined land use figures for the Iowa River and the adjacent Cedar River Basins are presented in Table 2.1.

Roads and residential and commercial development have not been of sufficient extent to have a large impact on the hydrologic and erosion/sedimentation characteristics of the basin.

2.5 WATER RESOURCES

2.5.1 Water Supply

All water in the Iowa River Basin originates from precipitation. There is no significant interbasin transfer of surface or subsurface water into the watershed.

The narrow valleys of the Iowa River are underlain by glacial and alluvial deposits including highly permeable sand and gravel. Parts of the tributary valleys also contain such deposits, but their location is not known accurately. Despite the large supplies of ground water available from these sand and gravel deposits, little use has been made of this source and therefore little information is available concerning the thickness and hydraulic properties of the deposits.

TABLE 2.1 LAND USE IN THE IOWA-CEDAR RIVERS BASIN
(From U.S. Department of Agriculture, 1976)

Land Use	Total Basin % of Area	North Area* % of Area	South Area % of Area
Cropland	73.3	81.3	65.7
Farmstead	2.4	2.4	2.3
Hayland	3.2	1.5	4.8
Grassland	10.5	6.3	14.6
Recreation	*	*	*
Transportation	2.7	2.8	2.6
Forest Land	2.7	1.4	4.0
Urban	1.7	1.5	2.0
Wildlife	0.7	0.3	1.0
Streams	-	-	-
Wetlands	0.7	0.6	0.8
Lakes & Ponds	0.2	>0.1	0.3
Windbreaks	0.3	0.5	0.2
Odd Areas	0.4	0.4	0.5
Fence Rows	0.6	0.5	0.6
Waterways	0.6	0.5	0.7
Other	>0.1	>0.1	>0.1

* THE DIVIDING LINE BETWEEN THE NORTH AREA AND THE SOUTH AREA IS THE NORTHERN BOUNDARIES OF STORY, MARSHALL, TAMA, BENTON, AND LINN COUNTIES.

2.5.2 Water Quality

The most significant pollution problems in the Iowa River are low dissolved oxygen and high turbidity, primarily the result of high organic loadings from nearby municipal and industrial sources and agricultural nonpoint sources. Dissolved oxygen levels have often been found in violation of Iowa stream standards. Turbidity problems are even more significant; the Iowa River has the worst turbidity of any eastern Iowa river.

During periods of heavy rainfall on recently worked agricultural land without good soil erosion practices, topsoil losses in the Iowa River Basin can be tremendous (University of Iowa, 1976). Individual suspended solids samples have recorded values as high as 13,000 mg/l, and record daily sediment loadings at Marengo for the period of 1974-1978 had a maximum value of 432,000 Tonnes/day (475,000 tons/day), which corresponds to a loss of 0.7 Tonnes/ha (0.3 tons/ac) for one day averaged over the entire basin.

Elevated values for several pesticides and certain heavy metals have also been found in the Iowa River. In most cases, elevation of the various parameters paralleled increases in turbidity and are directly related to turbidity (University of Iowa, 1976). The Iowa Department of Environmental Quality reports the presence of DDE, DDT, dieldrin, and atrazine in the Iowa River. In addition, sampling programs carried out by the University of Iowa have found measurable quantities of alachlor, trifluralin, Dyfonate, chlordane, heptachlor, and heptachlor epoxide (University of Iowa, 1976). DDE, DDT, and dieldrin have been found in concentrations which exceed recommended maximum levels established by the National Academy of Science. Heavy metals found in the Iowa River have included barium, copper, lead, manganese, zinc, and selenium. Only copper has been found in violation of Iowa standards (Iowa Dept. of Environmental Quality, 1976).

SECTION 3

AVAILABILITY AND SELECTION OF TIME SERIES DATA

3.1 HSPF TIME SERIES DATA REQUIREMENTS

Hydrologic and sediment simulation using HSPF requires the following time series data:

1. precipitation
2. potential evapotranspiration
3. streamflow
4. sediment
5. water temperature
6. air temperature
7. wind speed
8. solar radiation
9. dewpoint temperature

Of the meteorological time series, precipitation and potential evaportranspiration are direct determinants of water availability while air temperature, wind speed, solar radiation, and dewpoint temperature are all primarily used to calculate accumulation and melt of snow. Water temperature data is required for the instream sediment simulation, and observed streamflow and sediment loadings or concentrations are used for comparison with simulated results.

3.2 AVAILABLE DATA

There are 18 NOAA weather stations in or near the 7,236 sq. km Iowa River Basin above Marengo. The stations and the type of data available at each station are presented in Table 3.1, and the location of each station in relation to the watershed boundary is shown in Figure 3.1. Additional meteorologic data were available from the Iowa State University and Four Mile Creek Weather Station near Traer. Precipitation, maximum and minimum air temperatures, humidity, pan evaporation, solar and net radiation have been recorded at this station. However, the station was closed during winter months and has experienced numerous equipment failures; consequently, records are incomplete.

The United States Geologic Survey currently maintains nine stream gages in the Iowa River Basin. The locations of these gages are listed in Table 3.2 along with drainage area and period of record information. The stream gages can be located on Figure 3.1. In addition to these nine gages, records for two discontinued gages are available (W. Branch of Iowa River at Klemme and Iowa River at Belle Plaine).

Daily suspended sediment loadings data were available for the Iowa River at Marengo, Iowa. Sampling and analysis have been performed at this site by the U.S. Army Corps of Engineers on a continuous basis since 1968.

Water quality data for the Iowa River are limited. While the U.S. EPA data bank STORET contains data for various water

TABLE 3.1 STATION INDEX FOR IOWA RIVER BASIN METEOROLOGIC DATA

Station	Meteorologic Data *
Ames 8 WSW	P,T,E,O
Cedar Rapids FAA AP	P,T,O
Des Moines WSFO AP	P,T,O
Forest City	P,T
Grinnel 3 SW	P,T
Iowa City	P,T,E
Iowa City Ralston 2	P
Iowa City Ralston 5	P
Iowa City Ralston 6	P
Iowa Falls	P,T
Marshalltown	P,T
Mason City FAA AP	P,T,O
North English	P
Ottumwa FAA AP	P,T,O
Sheffield	P
Traer	P
Waterloo WSO AP	P,T,O
Webster City	P,T

P=hourly precipitation
E=daily potential evapotranspiration
T=daily max-min temperature
O=other daily meteorologic data
  (dewpoint temp., wind speed).

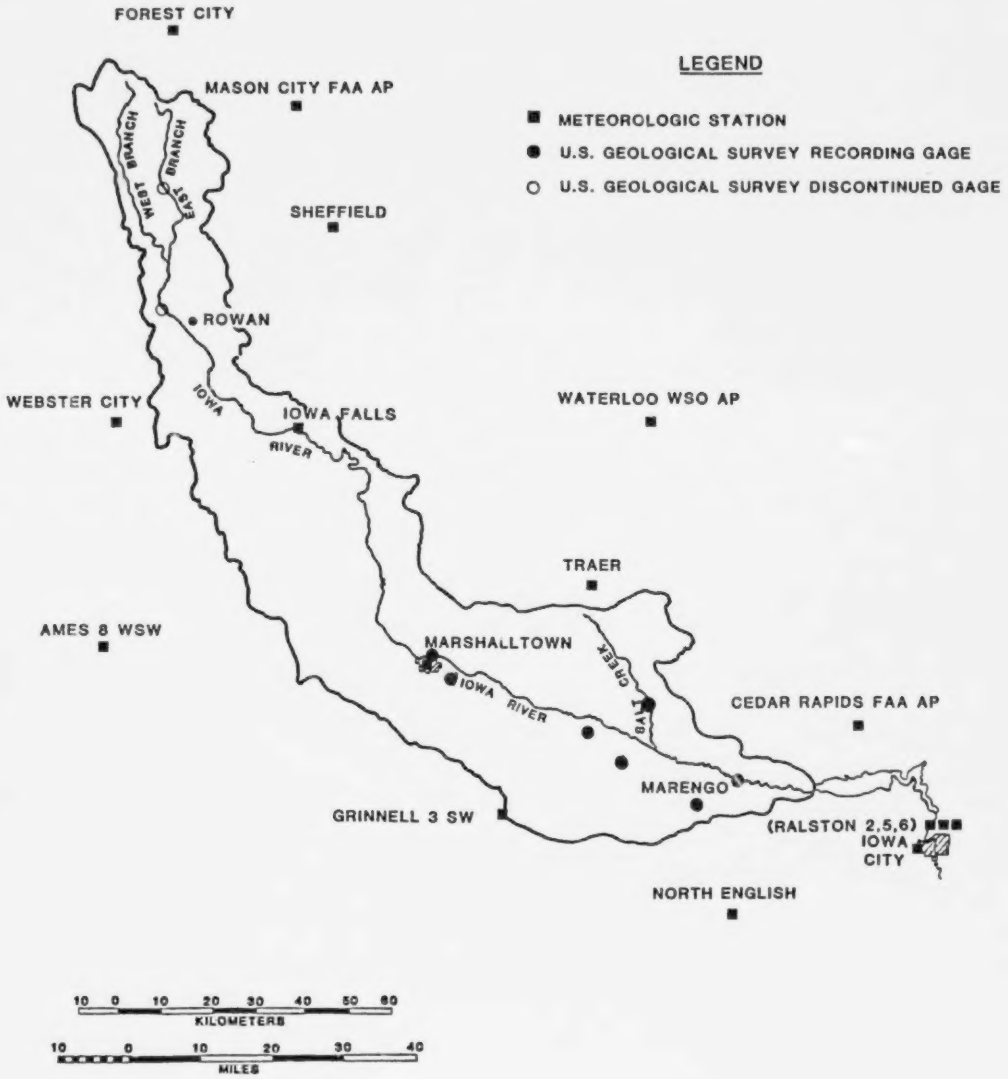

LEGEND
■ METEOROLOGIC STATION
● U.S. GEOLOGICAL SURVEY RECORDING GAGE
○ U.S. GEOLOGICAL SURVEY DISCONTINUED GAGE
FOREST CITY
MASON CITY FAA AP
WEST BRANCH
EAST BRANCH
SHEFFIELD
ROWAN
WEBSTER CITY
IOWA RIVER
IOWA FALLS
WATERLOO WSO AP
TRAER
AMES 8 WSW
MARSHALLTOWN
SALT CREEK
IOWA RIVER
CEDAR RAPIDS FAA AP
MARENGO
GRINNELL 3 SW
(RALSTON 2,5,6)
IOWA CITY
NORTH ENGLISH
10 0 10 20 30 40 50 60
KILOMETERS
10 0 10 20 30 40
MILES

Figure 3.1 Meteorologic and USGS gaging stations in and near the Iowa River Basin.

TABLE 3.2 USGS STREAM GAGES IN THE IOWA RIVER BASIN

Station No.	Location	Drainage Area (km2)	Period of Record
4490	East Branch of the Iowa River at Kleme	344	1948-76
4495	Iowa River near Rowan	1111	1940-76
4515	Iowa River at Marshalltown	4051	1932-pres.
4517	Timber Creek near Marshalltown	306	1949-pres.
4519	Richland Creek near Haven	145	1949-pres.
4520	Salt Creek near Elberon	521	1945-pres.
4522	Walnut Creek near Hartwick	184	1949-pres.
4530	Big Bear Creek at Ladora	490	1945-pres.
4531	Iowa River at Marengo	7236	1956-pres.

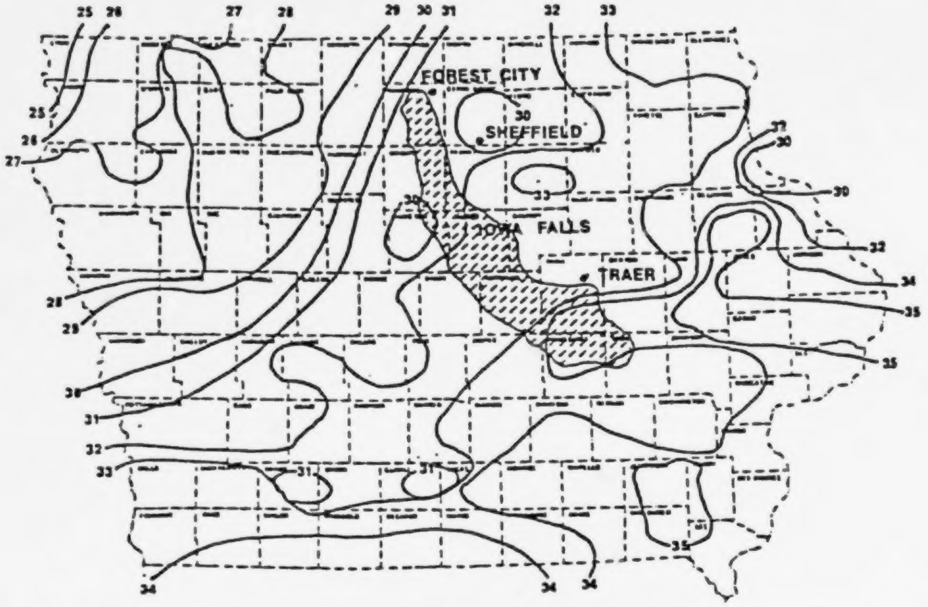
quality constituents at 29 locations along the river, sampling at most locations was infrequent and did not provide information on temporal variations of chemical concentrations which is needed for model calibration. Pesticide data were limited to a handful of grab samples at various sites along the Iowa River and at Coralville Reservoir and Lake Rathbun in south central Iowa.

3.3 SELECTION OF DATA FOR MODELING

In the following subsections the criteria used to select meteorologic and streamflow data for the Iowa River Basin simulation are outlined. Each data type is summarized separately since the selection procedure varied depending on availability of data for the 1974-1978 simulation period, spatial variability of the data type within the basin, and impact of the data type on simulation results.

3.3.1 Precipitation

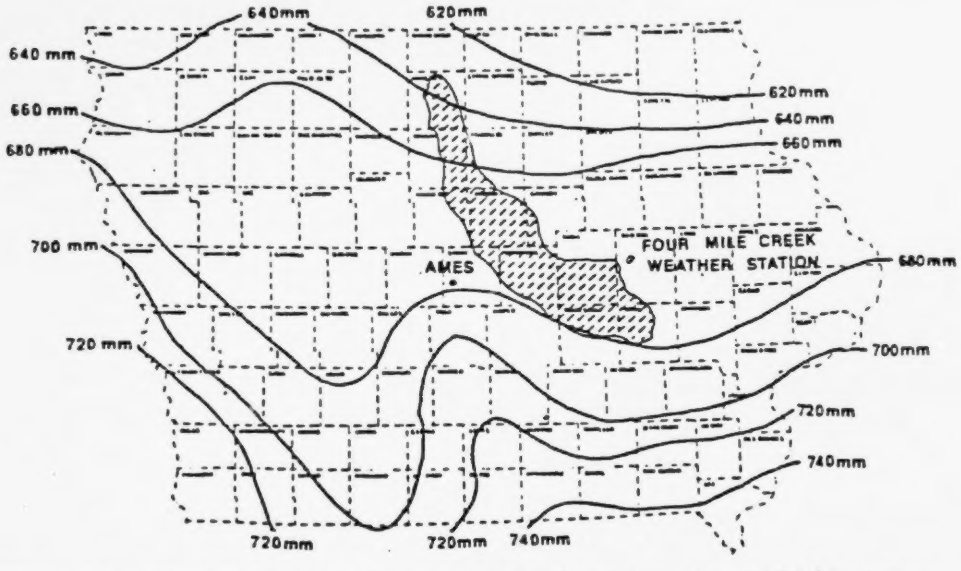
Mean annual precipitation for the basin varies from 76 cm (30 in.) in the north to 84 cm (33 in.) in the southeast (Figure 3.2). Given the primary importance of precipitation data to the simulated water balance, three records were used. Since the Traer rainfall record was used for the Four Mile Creek simulation (Donigian et al., 1983), and was already contained in the original HSPF Time Series Store (TSS), it was used as one of the three records for the Iowa River Basin. Both long term averages and records for the selected simulation period (1974-1978) suggested that the Traer precipitation was representative of the southeastern third of the basin, which



25
26
27
28
29
30
31
32
33
FOREST CITY
SHEFFIELD
IOWA FALLS
TRAER
34
35

Mean Annual Precipitation in Inches

• denotes data station used for HSPF simulation effort



640mm
620mm
640 mm
660 mm
680 mm
700 mm
720 mm
620mm
640mm
660mm
FOUR MILE CREEK WEATHER STATION
AMES
680mm
700mm
720mm
740mm
720mm
720mm
740mm

Mean Annual Potential Evapotranspiration in Millimeters

Figure 3.2 Isopleths of mean annual precipitation and potential evapotranspiration in Iowa, locations of data stations used in simulation are noted on maps. (adapted from Iowa Natural Resources Council, 1978)

receives 81-84 cm (32-33 in.).

The central section of the basin has a long term average annual precipitation in the range of 79-81 cm (31-32 in.), and was represented by the Iowa Falls record. The Iowa Falls station recorded an average of 76 cm of annual rainfall during the 1974-1978 simulation period, somewhat lower than the long term average (lower than average rainfall was recorded at all stations within the basin for the 1974-1978 period). The Iowa Falls record was generally good. Records were missing for 17 days, and were filled in using data from the Ames station.

The northern section of the basin is characterized by 76-79 cm (30-31 in.) of average rainfall. Inspection of the records for the two best candidate stations, Forest City, and Sheffield, showed large periods of missing data for both. Sheffield, was selected as the base record and was updated using Forest City data when available (43 days). Remaining gaps (53 days) were filled using Iowa Falls data.

3.3.2 Potential Evaportranspiration (PET)

Mean annual PET for the Iowa River Basin varies from 64 cm (25 in.) in the north to 68 cm (27 in.) in the far south (Figure 3.2). Three sets of PET data were available: Ames, Iowa City, and Four Mile Creek Weather Station. The record used for simulation was a composite of the Four Mile Creek Weather Station and Ames data. All data prior to July 1976 was from Ames, while that occurring after July 1976 was primarily Four Mile Creek Weather Station data, with missing values obtained from Ames. The 10-year (1969-1978) average annual PET for the combined record is 63 cm; this suggests that the record may be a little low for the southern portion of the basin. However, since the record was used successfully for the Four Mile Creek simulation, it was expected to be as effective or more effective in representing the PET for the overall basin. Hence, the Four Mile Creek data was used for the entire basin.

3.3.3 Streamflow

Of the nine streamflow records (Table 3.2), three of the gages are located on the main branch of the Iowa River and were used in the whole-basin calibration. These were:

1. Iowa River near Rowan; 1,111 sq. km (429 sq. mi.)
2. Iowa River at Marshalltown; 4,051 sq. km (1,564 sq. mi.)
3. Iowa River at Marengo; 7,236 sq. km (2,794 sq. mi.).

Of the remaining six gages, only one is located in the northern portion of the watershed, which is characterized by glaciated till, potholes, and low runoff. The record from this gage, the East Branch of the Iowa River at Klemme, was used to develop hydrologic calibration parameters for the northern area. The Salt Creek gage near Elberon, Iowa (Figure 3.1), was used to develop a second set of hydrologic calibration parameters for the southern area.

3.3.4 Sediment

Daily instream sediment loadings collected by the U.S. Army Corps of Engineers at Marengo for the period 1974-1978 were used as a basis for sediment calibration. Limited grab samples of suspended sediment at points upstream of Marshalltown were available from the University of Iowa; these were used as a check to assure that simulated instream sediment loadings from the northern watershed lands were reasonable.

3.3.5 Water Temperature

A yearly water temperature profile for the Iowa River was developed by interpolating between recorded values contained in the EPA STORET file for Iowa River sampling stations. Values for this profile ranged from 0 deg. C in January to 27 deg. C in late July and August. The developed profile was used for simulation of sediment transport in all reaches of the Iowa River for all years of the simulation period.

3.3.6 Snow Simulation Data

Simulation of snow is an important component of the hydrologic modeling effort on the Iowa River. Hence, it was necessary to select and make use of four additional types of time series data: air temperature, wind speed, solar radiation, and dewpoint temperature.

3.3.6.1 Air Temperature--

Long term records indicate a strong relationship between station latitude and mean annual air temperature (Figure 3.3). Short term records show more variability, but indicate that the 1974-1978 period was cooler than typical. Given the fact that the stations which are selected are used to represent

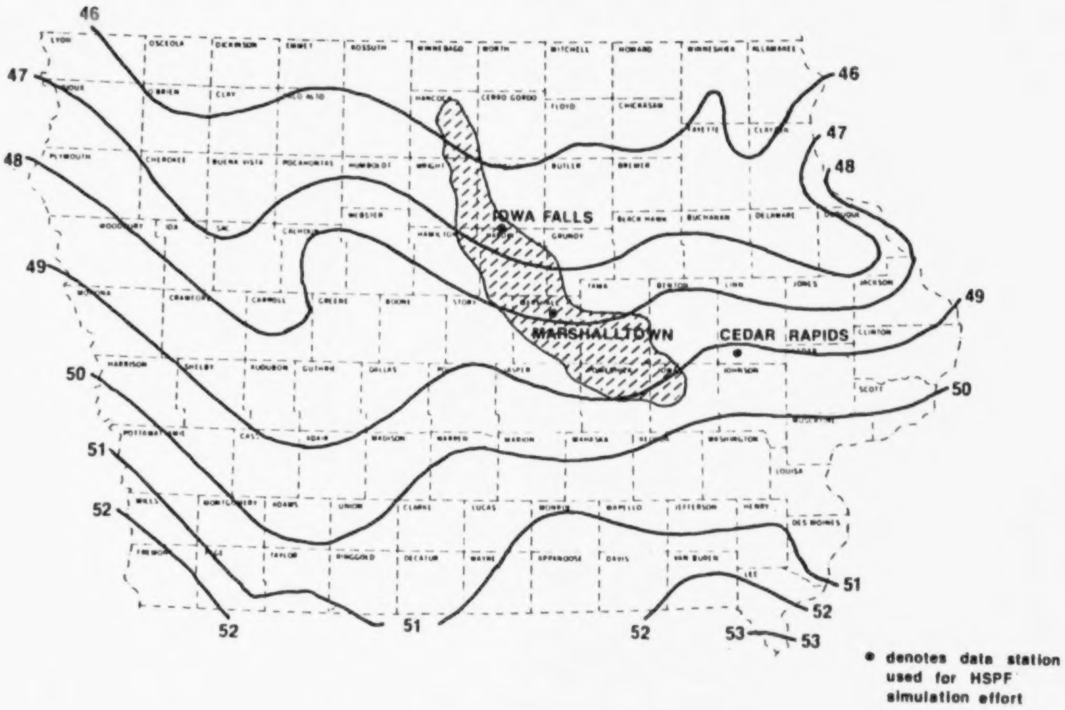

46
47
48
49
50
51
52
53
IOWA FALLS
MARSHALLTOWN
CEDAR RAPIDS
• denotes data station used for HSPF simulation effort

Figure 3.3 Isopleth of mean annual temperature (^{O}F) in Iowa (adapted from Iowa Natural Resources Council, 1978). Locations of data stations used in simulation are noted on map.

temperature characteristics over large areas of land, stations which exhibit reasonably close agreement between long and short term records are more likely to be representative of the large regions. Selection criteria used for air temperature records are listed below in order of importance:

1. Three stations were needed, one to represent each of the three basin sections delineated for the precipitation records.
2. Close agreement between long and short term records was desirable.
3. The short term record should be somewhat cooler than long term record.
4. Stations should be within the watershed boundaries.

Based on these criteria the three air temperature records chosen for the Iowa River Basin simulation were Iowa Falls, Marshalltown, and Cedar Rapids.

Iowa Falls - The station is located inside the watershed and its short term and long term records are similar. The mean annual temperature is about 8.6 deg. C (47.5 deg. F), and the record was used to represent the upper third of the basin.

Marshalltown - The station is located inside the watershed, and its short and long term records are similar, with the short term record somewhat cooler. The mean annual temperature is approximately 9.2 deg. C (48.5 deg. F), and the record was used to represent the middle portion of the basin.

Cedar Rapids - The mean annual temperature of this station is approximately 9.7 deg. C (49.5 deg. F), which makes the station representative of the lower portion of the basin. The short term mean annual temperature is similar but somewhat cooler than the long term record. The station is located outside of the watershed, but appears to better represent the lower third of the basin than any other station.

The quality of all three records is excellent, with a total of seven records missing for the entire simulation period. These records were filled in using data from nearby stations. All records consist of maximum and minimum air temperatures. These data were distributed to hourly values for use by HSPF.

3.3.6.2 Wind Speed--

Wind data for the state of Iowa do not vary greatly from station to station. Consequently, the wind data from Four Mile Creek Weather Station (corrected using Waterloo data), which were used for the Four Mile Creek simulation, were examined to determine whether the record would adequately represent the entire Iowa River Basin. Analysis showed that the mean average hourly wind speed over any given month of the 10-year Four Mile Creek record does not vary from the long term composite Iowa value for the same month by more than 1.6 km/hr. Comparison of mean annual wind speeds showed a composite statewide value of 12.2 km/hr. at 0.3 meters above the land surface versus a value of 12.1 km/hr. for the Four Mile Creek data. The Four Mile Creek record has considerable gaps in it and was updated for the Four Mile Creek simulation using Waterloo data. This composite record was used for the entire Iowa River Basin.

3.3.6.3 Solar Radiation--

Comparison was made between the Four Mile Creek Weather Station solar radiation data and that at Ames (approximately 80 kilometers away) to assess the variability of radiation within the basin area. For the 18 month period from July 1976 to December 1977 the records differed by 3%, with a maximum monthly variation of 20% for the month of March 1977. Given the limited variability in these two records, the radiation record which was used for the Four Mile Creek simulation was used to represent the entire Iowa River Basin. This record is a composite of Four Mile Creek Weather Station and Ames data. All data prior to July 1976 is from Ames, while that occurring after July 1976 is primarily Four Mile Creek Weather Station data, with missing values obtained from Ames.

3.3.6.4 Dewpoint Temperature--

Previous studies have shown similarity between average daily dewpoint temperature and minimum daily temperature. Comparison of these two values on a daily basis for a 60 day record at Waterloo verified this relationship. Given the fact that only one dewpoint record (Mason City) is available near the study basin, it was decided that the best representation of dewpoint temperature could be obtained by using daily minimum temperature records for the stations selected to represent air temperature for the three basin segments (Iowa Falls, Marshalltown, Cedar Rapids).

3.4 QUALITY OF SELECTED DATA

The time series data of most concern in an HSPF simulation are precipitation data. Successful hydrologic simulation relies on the use of rainfall records which adequately represent rainfall patterns over the entire segment of land for which they are used. Adequate representation of precipitation over a segment becomes more difficult as the size of the segment increases and as variability of weather patterns increases. In the Iowa River Basin three rainfall records were used to represent an area of 7,236 sq. km. Moreover, two of the three records (i.e., Traer, Sheffield/Forest City) were not from stations which were located in the study basin. Preliminary comparison of other candidate records showed a great deal of variability in both timing and magnitude of selected storms. Accurate representation of rainfall over the Iowa River Basin would best be accomplished by weighting and combining a number of nearby stations to synthesize more representative records for each of the land segments. However, time and resources did not allow this approach.

The meteorological data time series other than precipitation are all good quality records and should give a fair to good representation of meteorological conditions within the areas for which they are used.

Of the five streamflow records used for calibration, all but Rowan were complete for the entire simulation period (1974-1978). The Rowan record was missing data for the period October 1976 through June 1977. The USGS classifies the records at Rowan, Klemme, Marshalltown, and Elberon as being "good except in winter, which are poor." The Marengo streamflow data are rated as "good except in winter, which are fair."

The record for sediment loadings data at Marengo was complete for the entire simulation period. However, the daily loading values which have been calculated by the Corps of Engineers may underestimate total sediment loadings by missing periods of peak sediment loading during diurnal and storm event fluctuations.

The water temperature time series synthesized for the HSPF simulation of the Iowa River Basin is the least accurate of all the time series data. A yearly water temperature profile for the Iowa River was developed by interpolating between a limited number of recorded values available at Iowa River sampling stations. The developed profile was used for all reaches of the river and all 5 years of simulation. Since water temperature data are used solely to simulate sand transport and small variations in temperature have little effect on this simulation, the synthesized record should be more than adequate for the Iowa River simulation.

3.5 TIME SERIES DATA SUMMARY

Variability in meteorological patterns suggests the division of the Iowa River into a minimum of three segments in order to perform a reasonable hydrological simulation. As a consequence, for each meteorological data type a "best" record has been selected for representing the northern, central, and southeastern areas of the Iowa River watershed. These records are summarized in Table 3.3. Observed streamflow data for the East Branch at Klemme and Salt Creek at Elberon allow for development of preliminary values for hydrologic calibration parameters. Streamflow data along the main stem of the Iowa River at Rowan, Marshalltown, and Marengo allow three reference points for the actual hydrologic calibration of the Iowa River, and observed sediment loadings at Marengo permit instream sediment calibration at the downstream terminus of the study basin.

TABLE 3.3 SUMMARY OF BEST METEOROLOGIC DATA AVAILABLE TO REPRESENT THE THREE MAJOR SEGMENTS OF THE IOWA RIVER BASIN

	Source of Meteorologic Record used to Represent Each Area*		
Data Type	Meteorologic Set Number 3 (northern)	Meteorologic Set Number 2 (central)	Meteorologic Set Number 1 (southeastern)
precipitation	Sheffield/ Forest City	Iowa Falls	Traer
potential evapotranspiration	Station 36	Station 36	Station 36
air temperature	Iowa Falls	Marshalltown	Cedar Rapids
wind speed	Station 36/ Waterloo	Station 36/ Waterloo	Station 36/ Waterloo
solar radiation	Station 36/ Ames	Station 36/ Ames	Station 36/ Ames
dewpoint temperature	Iowa Falls (min. daily temperature)	Marshalltown (min. daily temperature)	Cedar Rapids (min. daily temperature)

* The second station noted in some entries was used to fill in missing data records in the primary station.

SECTION 4

WATERSHED SEGMENTATION FOR HSPF APPLICATION

4.1 PERVIOUS LAND SEGMENTATION

The segmentation of the watershed into separate pervious land segments (PLSs) for simulation by HSPF is based on an evaluation of the following factors:

1. meteorologic patterns
2. soils characteristics
3. land use

4.1.1 Meteorologic Patterns

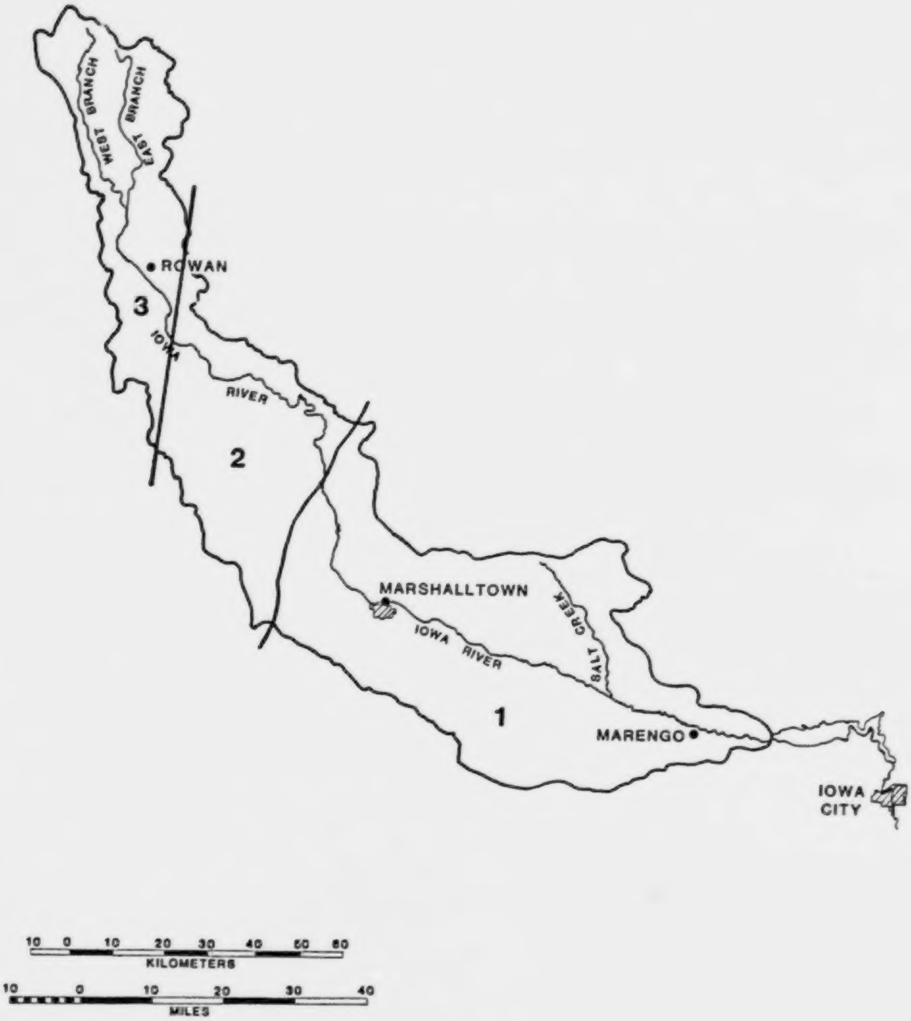
Variability in meteorology over the basin dictates that the Iowa River Basin be divided into at least three segment groups. Based on long term isopleth information on rainfall and air temperature, tentative boundaries for the segment groups were formulated, followed by a slight adjustment of boundaries based on spatial distribution of soils.

4.1.2 Soils Characteristics

The boundary between the Clarion-Webster and the Tama-Muscatine areas (Figure 2.2) was compared to the tentative boundary between the bottom two segment groups, as defined by meteorologic considerations. It was concluded that the soils association boundary would serve equally well as a boundary between the land represented by meteorologic data sets representing the central and the southeastern segments. The preliminary boundary between the two northern segment groups was drawn based on long term precipitation isohyets and the general breakpoint between the northern flatlands and the central hilly region. These preliminary segment group boundaries are delineated in Figure 4.1.

4.1.3 Special Considerations

A good deal of time and effort can be saved by defining segment group boundaries so that they are superimposed on the boundaries between contributing areas to the individual reaches. Contributing area boundaries, as delineated on Figure 4.2, were examined and it was decided that the preliminary segment group boundaries could be shifted and superimposed onto contributing area boundaries as shown on Figure 4.3. Thus, all land contributing runoff to reaches 1-6 is contained in segment group number 1 (southeastern segment); all land contributing runoff to reaches 7-11 is in segment group number 2 (central segment); and runoff to reaches 12 and 13 is wholly contributed by segment group number 3.



WEST BRANCH
EAST BRANCH
ROWAN
3
IOWA
RIVER
2
MARSHALLTOWN
SALT CREEK
IOWA
RIVER
1
MARENGO
IOWA CITY
10 0 10 20 30 40 50 60
KILOMETERS
10 0 10 20 30 40
MILES

Figure 4.1 Preliminary segmentation of the Iowa River Basin to account for variability in meteorologic patterns and soils characteristics.

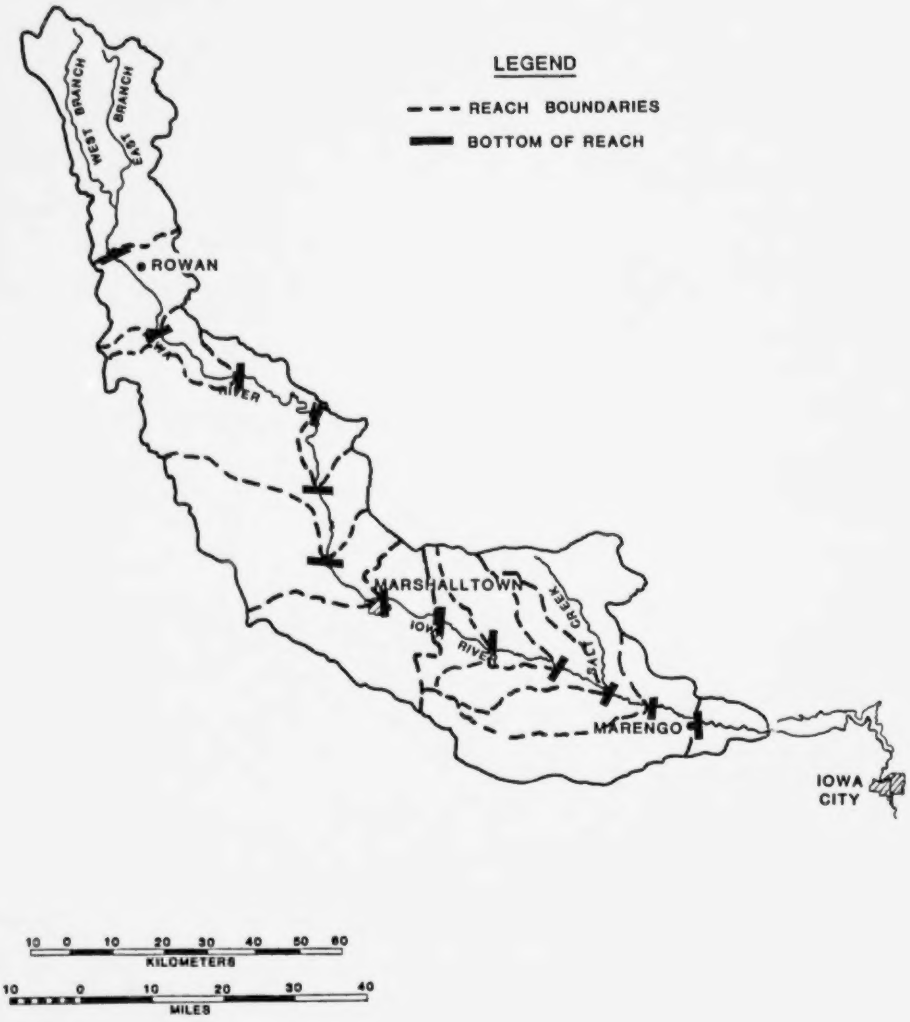

LEGEND
REACH BOUNDARIES
BOTTOM OF REACH
WEST BRANCH
EAST BRANCH
ROWAN
RIVER
MARSHALLTOWN
IOWA RIVER
SALT CREEK
MARENGO
IOWA CITY
10 0 10 20 30 40 50 60
KILOMETERS
10 0 10 20 30 40
MILES

Figure 4.2 Channel reaches and contributing areas for the Iowa River Basin.

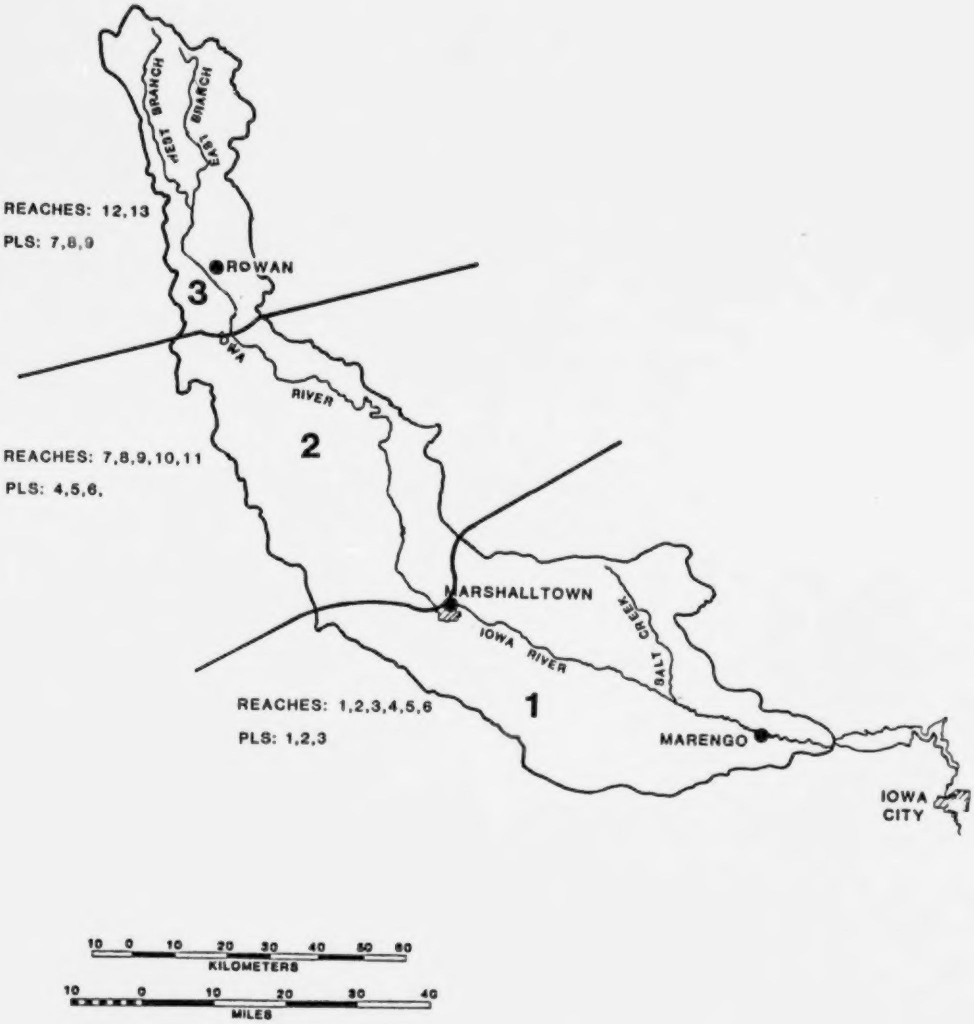

WEST BRANCH
EAST BRANCH
REACHES: 12,13
PLS: 7,8,9
ROWAN
3
IOWA
RIVER
2
REACHES: 7,8,9,10,11
PLS: 4,5,6,
MARSHALLTOWN
SALT CREEK
IOWA RIVER
1
REACHES: 1,2,3,4,5,6
PLS: 1,2,3
MARENGO
IOWA CITY
10 0 10 20 30 40 50 60
KILOMETERS
10 0 10 20 30 40
MILES

Figure 4.3 Final segmentation of the Iowa River Basin.

4.1.4 Final Pervious Land Segmentation

The final subdivision of segment groups into pervious land segments (PLSs) was based on land use. Land use types which have the largest impact on runoff or water quality response in the watershed were identified. For the Iowa River Basin, between 65 and 85% of each county is cropland. Of all other land use types, only grassland comprises more than 10% of the area's total usage.

A large majority of the croplands in the basin are planted in either corn or soybeans. Given the differences in fertilizer and pesticide application for the two crops, it was decided that each crop should be considered as a separate land use type. All lands not planted in corn or soybeans were considered as a third composite land use type. Thus, there were a total of nine pervious land segments (PLSs) for the Iowa River Basin - one to represent each of the three land use types in each of the three segment groups. The characteristics of the nine pervious land segments selected for the Iowa River Basin simulation are summarized in Table 4.1.

County land use data for 1976 from the report "1978 Iowa Agricultural Statistics" (Iowa Crop and Livestock Reporting Service, 1978) were used to determine the percentage of land in each county devoted to corn, soybeans, and other purposes. It was assumed that the relative amount of land devoted to each use was constant throughout the county. The contributing area to each hydraulic reach was subdivided on a county basis, and further subdivided into corn, soybeans, and other land based on the county-wide statistics. Total area devoted to

TABLE 4.1 DEFINITION OF PERVIOUS LAND SEGMENTS (PLSs) FOR THE IOWA RIVER BASIN

	Characteristics		
PLS#	Meteorology	Soils	Land Use
1	met. set # 1*	loess	soybeans
2	met. set # 1	loess	corn
3	met. set # 1	loess	other
4	met. set # 2	glacial till	soybeans
5	met. set # 2	glacial till	corn
6	met. set # 2	glacial till	other
7	met. set # 3	glacial till	soybeans
8	met. set # 3	glacial till	corn
9	met. set # 3	glacial till	other

---

* See Table 3.3 for description of meteorologic data

each of the land uses is summarized in Table 4.2 for each of the 13 subdivisions of the basin. Over the entire basin the estimated breakdown of land use was 45% corn, 22% soybeans, and 33% other uses. The total area of each of the nine pervious land segments is as follows:

PLS	Area (sq. km)	PLS	Area (sq. km)
1	515	6	655
2	1334	7	490
3	1443	8	707
4	588	9	303
5	1202	TOTAL........	7236

4.2 IMPERVIOUS LAND SEGMENTATION

Because of the low percentage of impervious land area in the basin, no impervious land segments were used in the simulation.

4.3 CHANNEL SEGMENTATION AND NETWORK

Segmentation of a river for simulation by HSPF requires consideration of channel characteristics such as cross-section shape and river bed slope and roughness, entry points of major tributaries, and locations of stream gages used for comparison of simulated and observed flow and sediment.

TABLE 4.2 LAND USE IN THE 13 CONTRIBUTING AREA SUBDIVISIONS IN THE IOWA RIVER BASIN

Reach	Contributing area (sq. km)	Area planted in corn (sq. km)	Area planted in soybeans (sq. km)	Other land use (sq. km)
1	860	321	111	427
2	847	332	140	376
3	355	140	60	155
4	269	106	47	117
5	238	98	41	98
6	723	337	117	269
7	927	445	197	285
8	995	495	259	241
9	122	62	28	31
10	202	101	49	52
11	199	98	54	47
12	391	184	129	78
13	1109	523	360	225
TOTAL...	7236	3243	1593	2400

4.3.1 Channel Characteristics

The basic channel characteristics for the Iowa River between the confluence of the east and west branches of the river and the USGS streamflow gage near Marengo are summarized below:

length:	300 km
slope:	0.00044 m/m or 0.44 m/km
flow-through time for mean flow:	7.0 days or 168 hours
velocity at mean flow:	0.5 m/sec or 1.8 km/hr.

The hydraulic routing algorithms used in HSPF are most accurate when flow time through individual reaches approximates the simulation time step. Since a 2-hour time step was used for routing, reach lengths should ideally have been approximately 3.6 km (1.8 km/hr. x 2 hours) in order for flow-through time for mean flow to meet this condition. If this criterion were followed, more than 80 reaches would be necessary for the Iowa River channel. For the purpose of this project, longer reaches, in the range of 15 to 30 km were used. The use of longer reaches reduced and spread out short time interval peaks, but effects were minimal on the mean daily values used for calibration.

A low-water profile for the Iowa River was prepared using USGS data (Heinitz, 1973). The profile (Figure 4.4) indicated a highly uniform slope for the entire 300 km stretch of river. A preliminary division of the river into reaches indicated that slopes range from 0.00026 to 0.00069 m/m. Consequently, slope was not a major consideration in reach definition for the Iowa River. USGS data indicated only one significant

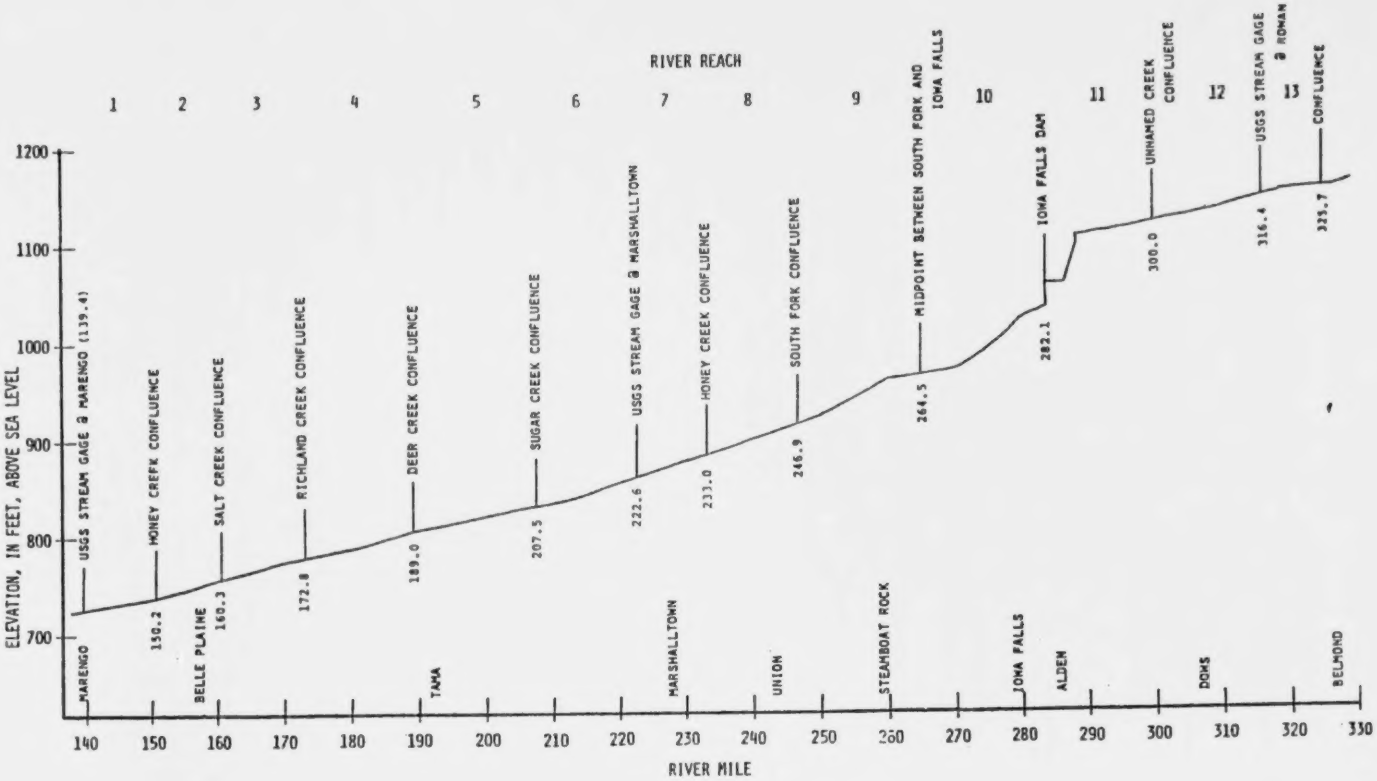


Figure 4.4 Iowa River low-water profile.

discontinuity in the channel bottom: a 7.3 m (24 ft) drop below the Iowa Falls Power Dam (Figure 4.4). The reservoir site was used as a reach boundary in the reach configuration.

4.3.2 FTABLE Definition

The hydraulic characteristics of each reach are specified in an FTABLE for use in the HSPF input sequence. FTABLEs specify values for surface area, reach volume, and discharge for a series of selected average depths of water in the reach; intermediate values are interpolated.

FTABLEs for reaches 1, 7, and 13 were developed using USGS cross-sections at gage sites and depth/discharge curves, combined with specified reach lengths. FTABLEs for reaches 2 through 6 were developed assuming that the slopes of the cross-sections were the same as that at Marengo, but that channel capacity decreased upstream from reach to reach. Both the width and depth coordinates of points on the Marengo cross-section were multiplied by a factor (< 1.0) consistent with relative top width data developed by Wallace (1971) for each of the reaches along the Iowa River. The adjusted cross-sections were input to an auxiliary computer program along with values for channel slope, Manning's n and flow. The program generated values for normal depth, cross-sectional area, and top width for a series of flow values at each reach cross-section, providing all the hydraulic data necessary to create the FTABLEs. The same procedure was used to develop FTABLEs for reaches 8 through 12 based on the cross-section slope at Rowan. Again, channel capacity was increased downstream from reach to reach by applying progressively larger multipliers (based on Wallace's data) to the coordinates of the Rowan cross-section. It should be noted that the Marshalltown cross-section was not used to generate other FTABLEs, because its shape was not considered representative of most stretches of the river (Wallace, 1971).

4.3.3 Reach Network Summary

The Iowa River was divided into 13 reaches for simulation. Of the 12 intermediate reach boundaries between the study limits, one was selected at the Iowa Falls Power Dam channel discontinuity; two were selected at USGS streamflow gage sites (Rowan and Marshalltown), eight corresponded to sites of major tributary inflow, and one was chosen arbitrarily to subdivide a section of river which was too long to be represented as one reach.

The 13 reaches and the contributing area to each reach are illustrated in Figure 4.3. Reach characteristics including limits, length, channel slope, and contributing area are summarized in Table 4.3 and the corresponding FTABLEs are shown in Table 4.4.

4.4 CONNECTIVITY OF LAND SEGMENTS AND STREAM REACHES

As described in Section 4.1.3 the segments for the Iowa River Basin were defined such that all land contributing runoff to reaches 1-6 is contained in segment group number 1 (PLSs 1, 2, and 3); all land contributing runoff to reaches 7-11 is in segment group number 2 (PLSs 4, 5, and 6); and runoff to reaches 12-13 is wholly contributed by segment group number 3 (PLSs 7, 8, and 9). Reference can be made to Table 4.2 to ascertain the breakdown of the contributing area for each reach into the three land use categories.

TABLE 4.3 REACH CHARACTERISTICS FOR THE IOWA RIVER

Description of Reach	Reach No.	Reach Length (km)	Channel Slope (m/m)	Contributing Area (sq. km)
Belmond to Gage at Rowan	13	15.0	.00026	1109
Gage at Rowan to Unnamed Creek Confluence	12	26.4	.00031	391
Unnamed Creek Confluence to Iowa Falls	11	28.8	.00066	199
Iowa Falls to Midpoint	10	28.3	.00069	202
Midpoint to South Fork Confluence	9	28.3	.00055	122
South Fork Confluence to Honey Creek Confluence	8	22.4	.00044	995
Honey Creek Confluence to Gage at Marshalltown	7	16.7	.00047	927
Gage at Marshalltown to Sugar Creek Confluence	6	24.3	.00033	723
Sugar Creek Confluence to Deer Creek Confluence	5	29.8	.00028	238
Deer Creek Confluence to Richland Creek Confluence	4	26.1	.00030	269
Richland Creek Confluence to Salt Creek Confluence	3	20.1	.00032	355
Salt Creek Confluence to Honey Creek Confluence	2	16.3	.00030	847
Honey Creek Confluence to Gage at Marengo	1	17.4	.00026	860
TOTAL		299.8	.00044	7236

TABLE 4.4 FTABLES FOR THE 13 REACHES USED IN SIMULATION OF THE IOWA RIVER BASIN

```
FTABLES

  FTABLE      1
 ROWS COLS                                         ***
  18    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU***
      (FT)   (ACRES) (ACRE-FT)     (CFS)     (HRS)***
       0.0       0.0       0.0       0.0       0.0
       4.0     250.0     579.9     270.0      26.0
       5.0     281.5     848.3     710.0      14.4
       6.0     294.5    1137.6    1210.0      11.4
       7.0     302.4    1437.4    1721.0      10.1
       8.0     307.6    1741.1    2258.0       9.3
       9.0     314.2    2048.7    2840.0       8.8
      10.0     322.0    2366.8    3490.0       8.2
      11.0     360.0    2700.7    4249.0       7.7
      12.0     435.9    3101.2    5120.0       7.3
      13.0     455.6    3543.7    6300.0       6.8
      14.0     484.4    4296.4    8206.0       6.3
      15.0     517.1    5364.6   10900.0       6.0
      16.0     549.8    6837.4   14730.0       5.6
      17.0     589.1    8960.7   20330.0       5.3
      18.0     628.4   11497.7   27490.0       5.1
      19.0     667.6   12188.9   36500.0       4.0
      25.0     905.0   16400.0   90560.0       4.0
  END FTABLE  1

  FTABLE      2
 ROWS COLS ***
  13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.517   184.249  267.8384  233.5109     832.7
     3.033   199.551  558.8862  753.5811     538.4
     4.550   214.854  873.1438 1507.3840     420.5
     6.067   230.158 1210.6110 2479.9080     354.4
     7.583   245.461 1571.2870 3666.0350     311.2
     9.100   260.763 1955.1730 5065.1170     280.2
    12.133   291.370 2792.5750 8510.6010     238.2
    15.167   321.975 3722.815012844.6200     210.4
    18.200   352.581 4745.890018105.8600     190.3
    24.267   847.719 8386.800034735.1900     175.3
    30.333  1342.85715031.540059649.6300     182.9
    36.400  1837.99524680.120095395.1800     187.8
  END FTABLE  2

  FTABLE      3
 ROWS COLS ***
  13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.433   210.732  288.9285  198.0271    1059.3
     2.867   229.040  604.0977  639.6987     685.6
     4.300   247.348  945.5090 1280.9470     535.9
     5.733   265.656 1313.1630 2109.7010     451.9
     7.167   283.964 1707.0570 3122.2200     396.9
     8.600   302.272 2127.1930 4318.5110     357.6

    11.467   338.889 3046.1910 7271.6710     304.1
    14.333   375.505 4070.156010996.9500     268.7
    17.200   412.120 5199.078015530.5400     243.0
    22.933   991.242 9222.035029932.8100     223.7
    28.667  1570.36616565.300051548.8900     233.3
    34.400  2149.48927228.850082592.3700     239.3
  END FTABLE  3

  FTABLE      4
 ROWS COLS ***
  13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
     1.383   262.472  347.2415  191.2105    1318.4
     2.767   285.382  726.1736  617.7407     853.4
     4.150   308.291 1136.7960 1237.1120     667.1
     5.533   331.200 1579.1110 2037.7360     562.6
     6.917   354.109 2053.1160 3016.0610     494.2
     8.300   377.018 2558.8100 4172.1520     445.3
    11.067   422.836 3665.2770 7026.7810     378.7
    13.833   468.654 4898.503010628.8100     334.6
    16.600   514.472 6258.488015013.5400     302.6
    22.133  1238.83211109.270028952.0300     278.6
    27.667  1963.19519968.200049882.5400     290.6
    33.200  2687.55732835.260079952.6200     298.2
  END FTABLE  4
```

(continued)

TABLE 4.4 (continued)

```
 FTABLE       5
ROWS COLS                                              ***
  16    4
    DEPTH       AREA     VOLUME       DISCH  FLO-THRU***
     (FT)   (ACRES) (ACRE-FT)       (CFS)     (HRS)***
      0.0       0.0       0.0         0.0       0.0
      1.0     103.2      51.6        10.0      62.5
      1.8     188.4     170.4        50.0      41.3
      2.3     246.7     287.0       100.0      34.8
      3.5     347.6     634.6       300.0      25.7
      4.2     374.5     888.0       500.0      21.5
      5.5     405.9    1390.3      1000.0      16.9
      7.3     430.5    2159.5      2000.0      13.1
     10.0     468.7    3374.8      4000.0      10.2
     12.2     491.1    4408.6      6000.0       8.9
     13.9     515.8    5274.2      8000.0       8.0
     15.4     531.5    6070.2     10000.0       7.4
     18.1     550.0    7491.9     14000.0       6.5
     20.5     570.0    8902.4     18000.0       6.0
     23.0     590.0   10090.0     22000.0       5.6
     30.0     700.0   16000.0     39000.0
 END FTABLE  5

 FTABLE       6
ROWS COLS                                              ***
  17    4
    DEPTH       AREA     VOLUME       DISCH  FLO-THRU***
                                              (HRS)***

      0.0       0.0       0.0         0.0       0.0
      1.0      82.4      38.4        10.0      46.6
      1.7     150.1     130.0        50.0      31.5
      2.3     195.8     219.6       100.0      26.6

      3.3     265.4     479.5       300.0      19.4
      4.1     289.2     675.4       500.0      16.4
      5.3     305.7    1046.9      1000.0      12.7
      6.3     316.6    1352.6      1500.0      10.9
      7.1     327.6    1625.3      2000.0       9.9
      9.9     353.2    2549.6      4000.0       7.7
     12.0     375.2    3316.5      6000.0       6.7
     13.7     395.3    3966.3      8000.0       6.0
     15.2     413.0    4564.8     10000.0       5.5
     16.6     430.0    5117.5     14000.0       4.4
     18.0     450.0    5673.9     18000.0       3.8
     19.4     470.0    6223.0     22000.0       3.4
     25.0     560.0    8500.0     38000.0
 END FTABLE  6

 FTABLE       7
ROWS COLS                                              ***
  11    4
    DEPTH       AREA     VOLUME       DISCH  FLO-THRU***
     (FT)   (ACRES) (ACRE-FT)       (CFS)     (HRS)***
      0.0       0.0       0.0         0.0       0.0
      1.0     181.5     110.9       163.8       8.2
      2.0     277.3     344.1       460.7       9.0
      4.0     332.8     934.1      1389.0       8.2
      6.0     385.7    1651.4      2660.0       7.5
      8.0     534.5    2622.0      4197.0       7.6
     10.0     557.2    3706.2      6718.0       6.7
     12.0     584.9    4853.3     10880.0       5.4
     13.0     611.4    5798.8     14860.0       4.7
     14.0     642.9    7563.6     20460.0       4.5
     33.3    1800.0    20000.     65000.0       3.7
 END FTABLE  7

 FTABLE       8
ROWS COLS                                              ***
  19    4
    DEPTH       AREA     VOLUME       DISCH  FLO-THRU***
     (FT)   (ACRES) (ACRE-FT)       (CFS)     (HRS)***
      0.0       0.0       0.0         0.0       0.0
      0.6     160.1      45.5        10.0      55.2
      1.4     203.9     195.4       100.0      23.7
      2.3     217.3     385.8       300.0      15.6
      2.9     227.5     534.1       500.0      13.0
      4.2     246.0     837.4      1000.0      10.2
      5.2     259.5    1091.8      1500.0       8.8
      6.1     271.3    1320.9      2000.0       8.0
      6.9     283.1    1536.6      2500.0       7.5
      7.6     293.2    1737.1      3000.0       7.0
      8.8     310.0    2114.5      4000.0       6.4
     10.8     350.4    2783.4      6000.0       5.6
     12.6     382.5    3410.0      8000.0       5.2
     13.9     420.0    3930.8     10000.0       4.8
     15.2     500.0    4407.6     12000.0       4.5
     16.3     600.0    4852.4     14000.0       4.2
     17.4     750.0    5305.7     16000.0       4.0
     18.5     900.0    5676.3     18000.0       3.8
     42.8    1200.0    15000.     52000.0       3.5
 END FTABLE  8
```

(continued)

TABLE 4.4 (continued)

```
  FTABLE      13
 ROWS COLS                                                ***
   16    4
     DEPTH        AREA    VOLUME        DISCH   FLO-THRU***
      (FT)     (ACRES) (ACRE-FT)        (CFS)      (HRS)***
       0.0         0.0       0.0          0.0        0.0
       0.5        94.7      36.4         11.8       36.9
       1.0       112.7      89.4         48.8       22.0
       2.0       120.6     205.2        152.0       16.2
       3.0       130.8     331.4        308.0       13.0
       4.0       142.9     466.7        504.0       11.2
       5.0       151.0     613.2        744.0       10.0
       6.0       160.1     768.8       1070.0        9.1
       6.5       164.6     850.0       1220.0        8.4
       7.5       174.7    1090.1       1750.0        7.5
       8.5       186.0    1454.2       2580.0        6.8
       9.5       197.3    2014.4       3860.0        6.3
      10.5       214.2    2660.4       5500.0        5.9
      15.0       676.0   11000.0      23000.0
      20.0      1352.0   19000.0      40000.0
      25.0      2700.0   25000.0      52000.0
  END FTABLE 13
 END FTABLES

FMB121
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SECTION 5

HSPF CALIBRATION AND VERIFICATION

5.1 OVERVIEW AND SPECIAL PROBLEMS

The calibration process is performed to adjust model parameters so that simulated and observed system outputs agree within some measure of acceptance. Typically, this is accomplished in several stages. The logical order is to calibrate land segment hydrologic processes followed by stream hydraulics in order to properly simulate watershed hydrologic response. Simulated watershed outputs and changes in storage are compared whenever possible to observed values. Next, sediment washoff from the land surface followed by instream sediment process calibration is performed. After the system is calibrated, the simulation results are verified by simulating the outputs for a different period of time and comparing them to observed outputs.

The Iowa River Basin calibration was performed in the above manner and followed the general procedures discussed in the HSPF Application Guide (Donigian, et al., 1984). The results of the hydrologic calibration were evaluated using three main methods: comparison of simulated and observed annual and monthly runoff volumes; comparison of simulated and observed flow frequency curves; and comparison of simulated and observed hydrographs. Following these comparisons several statistical tests, described below, were performed to further evaluate the calibration results. Likewise for the sediment calibration, several comparisons between simulated results and estimated or observed values were made to evaluate the simulation of sediment processes. These included: simulated sediment washoff loads and gross erosion estimates for the various land use types; simulated and observed instream sediment loadings at the outlet of the basin; simulated and observed frequency curves of the instream concentrations; and the simulated and observed stability of the channel (i.e., degradation or aggradation).

A number of special problems were encountered in the Iowa River simulation. In some cases there was sufficient time and a means to compensate for the problems; in other cases there was either insufficient time and resources or no clear-cut means of correcting a problem. The major problems involved in the Iowa River simulation and the corrective actions taken, if any, are discussed below.

By far the greatest concern in the Iowa River Basin simulation was the adequacy of the three selected rainfall records in representing the 7200 sq. km watershed. As was mentioned previously, two of the three chosen records (Traer and Sheffield/Forest City) were not located within the basin boundaries, and comparison of records from the selected stations with those from other nearby stations showed a great deal of variability in both timing and magnitude of selected storms. The degree of variability is illustrated in Figures 5.1 and 5.2. Figure 5.1 shows the recorded rainfall totals for the months of June and July 1978 at eight stations near the upper segment group of the basin. The rainfall record

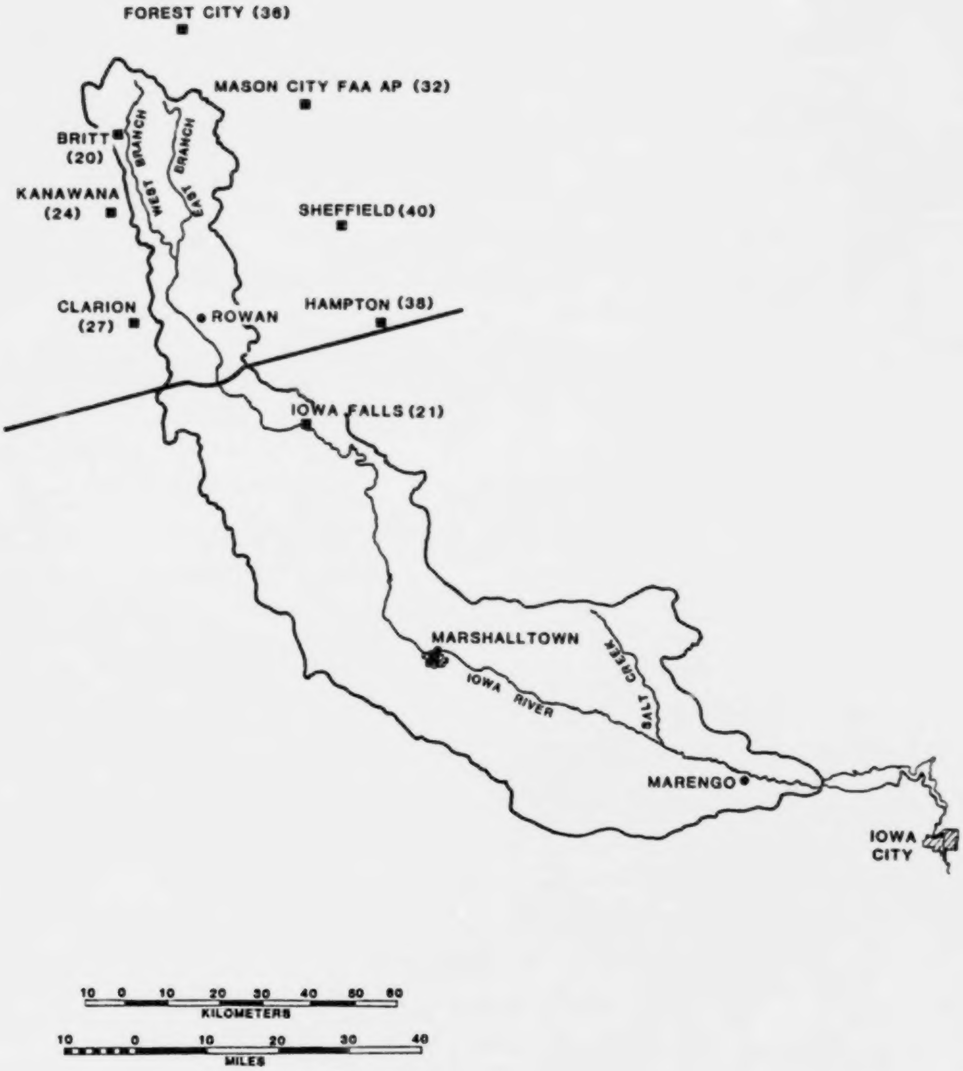

FOREST CITY (36)
MASON CITY FAA AP (32)
BRITT (20)
KANAWANA (24)
WEST BRANCH
EAST BRANCH
SHEFFIELD (40)
CLARION (27)
ROWAN
HAMPTON (38)
IOWA FALLS (21)
MARSHALLTOWN
IOWA RIVER
SALT CREEK
MARENGO
IOWA CITY
10 0 10 20 30 40 50 60
KILOMETERS
10 0 10 20 30 40
MILES

Figure 5.1 Variability in recorded rainfall totals for the months of June and July 1978 at stations near the upper segment group of the Iowa River Basin. Totals are expressed in centimeters. The Sheffield record was used for simulation.

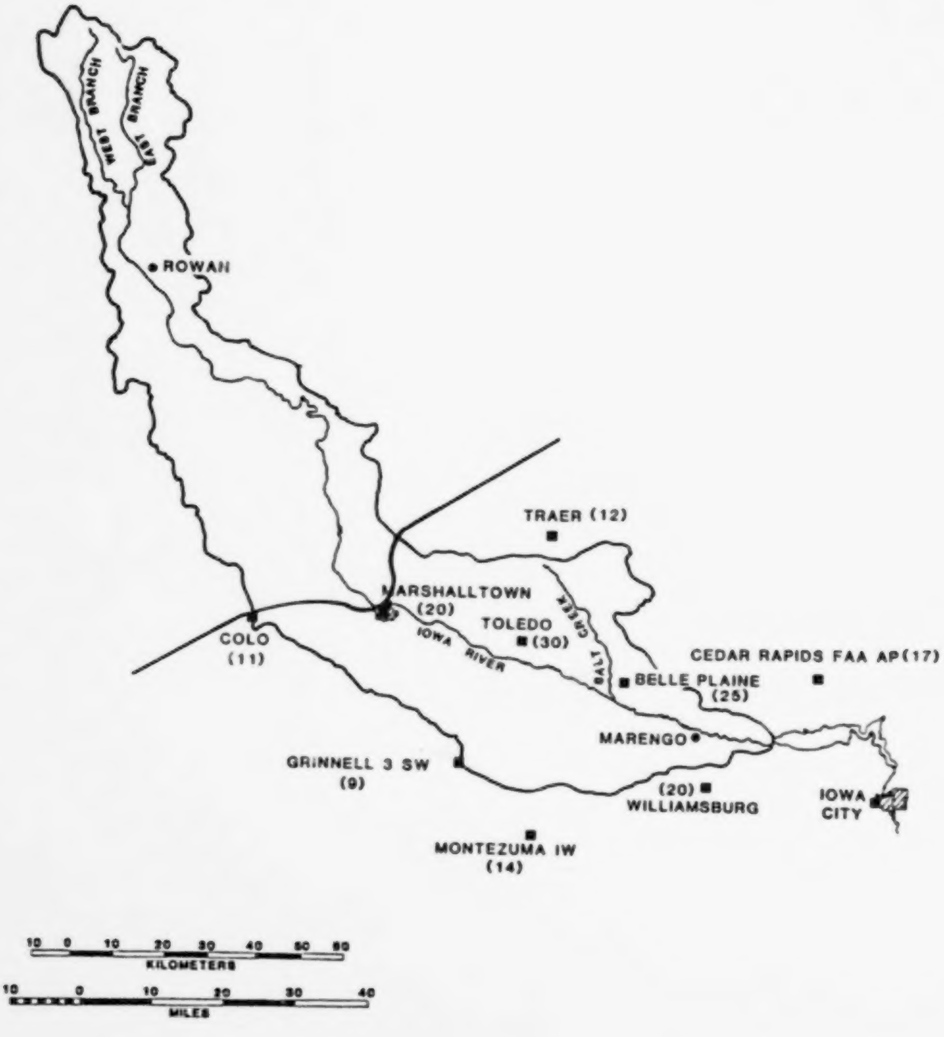

WEST BRANCH
EAST BRANCH
ROWAN
TRAER (12)
MARSHALLTOWN
(20)
TOLEDO
(30)
SALT CREEK
IOWA RIVER
COLO
(11)
CEDAR RAPIDS FAA AP(17)
BELLE PLAINE
(25)
MARENGO
GRINNELL 3 SW
(9)
(20)
WILLIAMSBURG
IOWA
CITY
MONTEZUMA IW
(14)
10 0 10 20 30 40 50 60
KILOMETERS
10 0 10 20 30 40
MILES

Figure 5.2 Variability in recorded rainfall totals for the month of August 1974 at stations in or near the lower segment group of the Iowa River Basin. Totals are expressed in centimeters. The Traer record was used for simulation.

(Sheffield) which was used for simulation is the highest of all eight stations and differs by as much as 100% with the station (Britt) recording the lowest rainfall for the two month period. Even a greater degree of variability in records is illustrated in Figure 5.2 for the month of August 1974 at nine stations in or near the lower segment group of the basin. In this case the station (Traer) used for simulation recorded only 40% as much monthly rainfall as the Toledo station, which is located centrally in the lower segment. (It should be noted, however, that the Toledo station was not an hourly recording gage and hence was not a candidate station for representing the lower segment). Given these variations in rainfall patterns, it is not likely that any three records could effectively represent the basin segments. Accurate representation of rainfall over the Iowa River Basin would best be accomplished by weighting and combining a number of nearby stations to synthesize more representative records for each of the land segments. However, time and resources did not allow this approach. In order to make the three selected rainfall records more representative of average meteorologic conditions over the segment groups, isohyetal maps were used to compare long term meteorologic patterns in each segment group to mean characteristics at each of the stations used for the simulation. For each segment group a multiplier was developed and applied to all precipitation data. The multipliers are listed below:

	Precipitation Representation
upper segment group	0.95 * Sheffield/Forest City precipitation data
middle segment group	0.98 * Iowa Falls precipitation data

lower segment group 1.03 * Traer precipitation data

A final correction was made to the rainfall records to improve the meteorologic representation of the basin for three storms which occurred in 1978. Areal variability for these storms was so great that an acceptable simulation of the 1978 period could not be expected without adjustment of the volumes of these storms. Based on comparison of records from all nearby stations, an areal average was established for each of these storms and the rainfall volumes for the station records used for simulation were adjusted accordingly. The dates of the storms, the station records adjusted, and the magnitude of adjustment are summarized below:

April 17-18, 1978	Sheffield record adjusted from 5.3 cm to 3.8 cm total rainfall; Iowa Falls record adjusted from 8.6 cm to 5.6 cm total rainfall
June 14-15, 1978	Sheffield record adjusted from 8.9 cm to 4.6 cm total rainfall
July 05-06, 1978	Sheffield record adjusted from 12.2 cm to 5.1 cm total rainfall

Another major problem anticipated with the hydrologic simulation was the timing and volumes of snowmelt runoff. Modeling snow accumulation, melt, and resulting runoff is a traditional weakness in watershed modeling; more research, algorithm development, and data is needed to better represent the full spectrum of relevant processes. For example, the occurrence and effects of frozen ground conditions are not well understood quantitatively, but they exert major impact on snowmelt runoff. During most years in Iowa, the snow pack melts in a short 2 to 3 week period producing a peak flow in about mid-March; the model generally produces an earlier, more gradual melting and lower peak flows. These problems are likely due to deficiencies in both the model (e.g., frozen ground, storage of melt in the snow pack) and the input meteorologic data, primarily air temperature and solar radiation. In an attempt to account for frozen ground effects, input values for infiltration capacity were reduced during the winter months. To assure that selected air temperature records were representative of average conditions over the segment groups, an isopleth map for air temperature (Figure 3.3) was used to compare long term air temperature patterns in each segment group to mean characteristics at each of the stations. The following multipliers were developed and applied to all air temperature data:

	Air Temperature Representation
upper segment group	0.88 * Iowa Falls air temperature data
middle segment group	0.92 * Marshalltown air temperature data
lower segment group	0.98 * Cedar Falls air temperature data

Another problem encountered in the Iowa River Basin simulation did not become apparent until the calibration effort was well under way. While a 5-year period of simulation is usually adequate to calibrate and verify the simulation of a watershed, the period of simulation was effectively shortened by record low flow conditions which occurred in 1976-1977, with 66% of normal annual streamflow recorded at the Marengo gage in 1976 and 47% of normal annual streamflow recorded in 1977. While it is useful to have extreme events in the period used to calibrate a watershed in order to ensure appropriate response to all meteorologic and hydrological conditions, the simulation period selected was already somewhat short; with the inclusion of two drought years in a 5-year simulation period, there were an insufficient number of flow events to rigorously calibrate the watershed. The results of the calibration are presented in the next section of this chapter.

It was recognized in the original Iowa River study that agricultural lands in Iowa demonstrate considerable seasonal variation in hydrologic response, due to weather patterns, tillage activities, and land cover/crop canopy changes. The following procedures were used in both studies for representing seasonal changes in the study basin:

1. Seasonal variation in land surface conditions was modeled by providing monthly values for interception storage, upper zone nominal storage, Manning's n for the overland flow path, and lower zone evapotranspiration.

2. The Special Actions section of HSPF was used to decrease infiltration for frozen ground conditions occurring between the winter freeze and spring thaw periods according to the following schedule:

upper segment group
spring thaw: 4/15
winter freeze: 12/01

middle segment group
spring thaw: 4/07
winter freeze: 12/08

lower segment group

spring thaw: 03/31
winter freeze: 12/15

3. The Special Actions routine was also used to increase the infiltration parameter for the effects of tillage on soybean and corn land beginning with the first tillage in the spring; the infiltration parameter was subsequently decreased to the nominal background value in later summer after compaction had negated the effects of tillage. The dates for both the spring and later summer adjustments were later in the northern watershed area and earlier in the southern area to coincide with the timing of tillage operations.

A final problem worth noting in this modeling study was the lack of edge-of-stream sediment loadings data for any part of the watershed, and the lack of instream sediment loadings data at any point except the downstream terminus (Marengo) of a 300 km stretch of river. As will be pointed out in Section 5.3, the lack of more extensive data somewhat hampered the sediment calibration effort.

5.2 HYDROLOGIC/HYDRAULIC CALIBRATION AND VERIFICATION

Much of the preliminary work leading up to final calibration and verification of the Iowa River Basin was performed in a previous demonstration application of HSPF to the study area (Imhoff et al., 1983). The goal of the current work was to refine the preliminary calibration efforts reported in that study. In addition a more thorough analysis of simulated and observed hydrological phenomena was carried out as a part of the current effort. A summary of the simulation procedures used in the preliminary study is useful prior to presentation of the final calibration and verification results.

Hydrologic simulation of the watershed was performed by modeling three segment groups, each of which was represented by one set of meteorological data (Section 3.3.1). Each segment group was divided into 3 pervious land segments to allow refinement of model parameters to properly represent differences in the hydrologic response of the major land use categories: soybeans, corn, and pasture/other lands (Section 4.1.4).

Parameter values developed to describe soil characteristics and the effects of agricultural activity in the Four Mile Creek watershed (Donigian, et al., 1983) were applied to corresponding segments in the nearby Iowa River Basin. Initial hydrologic simulations were performed on two test watersheds, one in the northern extreme of the basin (East Branch above Klemme, Iowa) and one in the south in the area nearest to Four Mile Creek (Salt Creek above Elberon, Iowa). The purpose of the test watershed simulations was to determine differences in local hydrologic response prior to simulating the entire watershed. Given the differences between the northern area and the remainder of the basin (Section 2.3) significant changes were necessary to the hydrologic parameter values, particularly for the northern group. Initial hydrologic simulation of the test watersheds resulted in oversimulation of runoff in the East Branch watershed and undersimulation of runoff in the Salt Creek watershed. Appropriate adjustments were made to parameter values through a number of calibration runs, and these more representative values were used for the initial calibration run of the entire basin. Two additional hydrologic calibration runs were made before the demonstration project was concluded.

Prior to the whole-basin simulation, an analysis of the effect on surface runoff of using a 1-hour 2-hour, and 4-hour simulation time step was performed on the Salt Creek test watershed. The results indicated that simulated surface runoff decreases with increasing length of time step, while the total runoff (i.e., surface, interflow, and ground water) remains essentially unchanged. For a 2-year period, simulation with a 2-hour time step resulted in a 5-10% reduction in surface runoff compared to a 1-hour time step; a 4-hour time step produced about 30% less surface runoff than the 1-hour time step. Based on these results a 2-hour time step was chosen for the Iowa River Basin simulation.

For the purposes of current study, the 5-year period (1974-1978) for which the data base was established was divided into calibration and verification periods of equal length. The January 1974 - June 1976 span was used for calibration. This period included a high-flow year (1974), an average flow year (1975) and the first 6 months of a low-flow year (1976). The verification period (July 1976 - December 1978) was characterized by continued lower than average flows until 1978, with the annual 1978 flows returning to a slightly higher than average level.

Table 5.1 provides yearly comparisons of recorded and observed runoff at the USGS streamflow gages (Rowan, Marshalltown, Marengo) in the study area for both the calibration and verification periods. Total runoff for the calibration period was oversimulated at Rowan by 8% and undersimulated at Marshalltown and Marengo by 14 and 3%, respectively. The final set of hydrologic calibration parameter values did not, however, result in an equally good simulation during the verification period. Due to previously noted rainfall problems, flow was significantly oversimulated at all three

TABLE 5.1 SUMMARY OF SIMULATED AND OBSERVED RUNOFF VOLUMES (cm)

Calibration

	Rowan			Marshalltown			Marengo		
Year	SIM	OBS	DIF(%)	SIM	OBS	DIF(%)	SIM	OBS	DIF(%)
1974	17.7	15.4	+ 15	25.5	31.3	-19	33.4	39.1	-15
1975	13.8	15.2	- 9	19.3	21.6	-11	25.1	23.4	+ 7
1976(1/1-6/30)	7.4	5.4	+ 37	11.4	12.4	- 8	13.9	12.5	+11

Verification

	Rowan			Marshalltown			Marengo		
Year	SIM	OBS	DIF(%)	SIM	OBS	DIF(%)	SIM	OBS	DIF(%)
1976(7/1-12/31)	0.2	0.5*	-	0.8	1.2	-33	1.7	1.4	+21
1977	4.6	0.9*	-	9.1	6.6	+38	12.5	9.8	+28
1978	23.3	10.2	+128	27.5	16.9	+63	34.5	22.7	+52
TOTAL....	67.0	47.7*	-	93.6	89.9	+ 4	121.1	108.9	+11

* does not include 10/76 - 6/77 runoff (observed data not available)

SIM = SIMULATED OBS = OBSERVED
DIF (%) = DIFFERENCE AS A % OF OBSERVED

stations with the resultant flow at Marengo being 44% greater than observed flow. Runoff totals for the entire 5-year period were oversimulated by 4% at Marshalltown and 11% at Marengo (total runoff at Rowan could not be calculated due to a gap from October 76 to June 1977 in the observed flow records).

In the application of HSPF to the Iowa River Basin, runoff was simulated from three components: surface water from pervious areas, interflow from pervious areas, and ground-water flow. Since the relative contribution of each component to observed streamflow records is unknown, contributions from each pathway were inferred from examination of hydrograph shape and timing for many events over a number of years of simulation. Table 5.2 provides a breakdown of the annual water balance by flow components for one representative year each of the calibration and verification periods. Both years shown have precipitation amounts slightly above the long term areal average (81 cm) for the basin. (Weighted areal average annual rainfall for the 1974 and 1977 simulation years were 88 and 86 cm, respectively.) The runoff response for the two years differed drastically due to antecedent conditions. While the areal average runoff/rainfall ratio for the 1974 simulation year varied from .25 in the upper segment group to .42 in the lower segement group, runoff for 1977 was depressed to a range of .06 to .18 for the same segment groups due to depletion of subsurface moisture storages resulting from the low rainfall year of 1976. The balances from both years indicate that subsurface flow is the primary contributor to runoff in the Iowa River Basin, with a basin wide average of 28% of total runoff being contributed by surface runoff in 1974, and 19%in 1977. Surface runoff from the pasture/other segments tended to be in the range of one-fourth to one-third as large as surface runoff from the croplands.

TABLE 5.2 TYPICAL ANNUAL WATER BALANCE (CALIBRATION AND VERIFICATION) FOR THE NINE SIMULATED PERVIOUS LAND SEGMENTS

Calibration - 1974

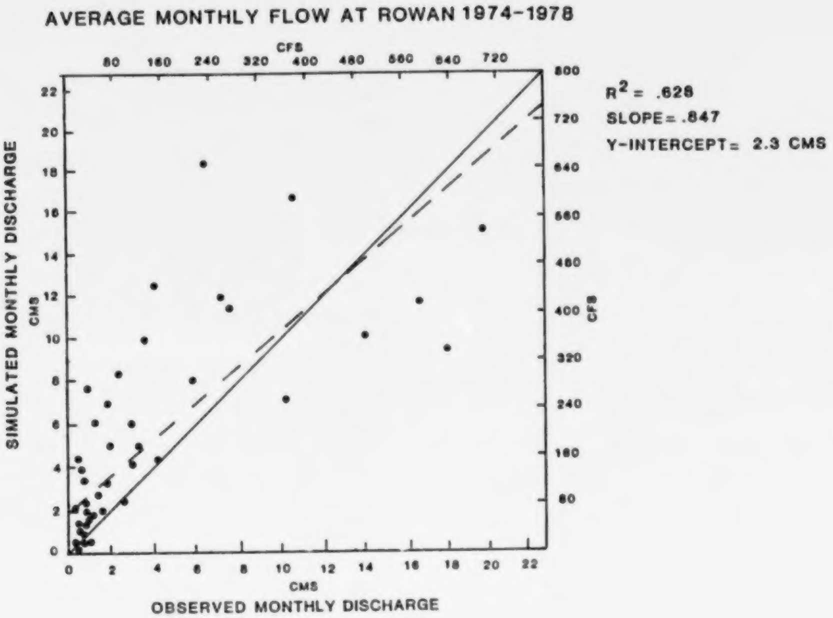
	Lower Segment Group			Middle Segment Group			Upper Segment Group		
cm	PLS 1 Beans	PLS 2 Corn	PLS 3 Other	PLS 4 Beans	PLS 5 Corn	PLS 6 Other	PLS 7 Beans	PLS 8 Corn	PLS 9 Other
Precipitation	102.2	102.2	102.2	80.3	80.3	80.3	70.1	70.1	70.1
Evapotranspiration	66.9	67.0	67.5	62.7	62.5	63.4	64.8	65.2	62.8
Runoff	42.6	42.2	43.5	30.6	30.8	29.8	17.9	17.7	17.5
Surface	14.6	15.4	6.5	11.9	12.8	4.9	3.9	4.2	1.1
Interflow	6.5	6.6	8.5	4.3	4.4	5.7	2.8	2.9	2.4
Ground water	21.5	20.4	28.5	14.4	13.7	19.2	11.2	10.6	14.0

Verification - 1977

cm									
Precipitation	92.8	92.8	92.8	81.9	81.9	81.9	75.8	75.8	75.8
Evaportranspiration	53.5	54.3	53.1	52.5	53.2	51.5	55.1	55.4	52.9
Runoff	18.2	16.9	16.7	12.5	11.4	12.6	4.6	4.3	5.9
Surface	5.3	4.9	1.1	2.6	2.4	0.7	0.9	1.1	0.5
Interflow	1.8	1.7	1.7	1.0	0.9	1.0	0.2	0.2	0.4
Ground water	11.1	10.2	13.9	8.9	8.1	10.9	3.5	3.1	5.0

Based on the channel configuration and characteristics developed in Section 4.3 kinematic wave routing was performed on the Iowa River Basin runoff within the 300 km of the main stream channel above Marengo. HSPF generated values for average daily flow at 13 points along the length of the channel; three of the designated points were Rowan, Marshalltown, and Marengo, and consequently a direct comparison could be made between simulated flows and USGS gage records at the sites. To further evaluate the simulation of runoff volumes, scattergrams of simulated vs. observed monthly flows were plotted. Results for the simulation period (1974-1978) are shown in Figure 5.3 for each of the three gages. In addition, correlation analyses were performed on the mean monthly flow data as well as for mean daily flows and 3-day average flows. Correlation coefficient (i.e., R-squared) values from these analyses are listed in Table 5.3. A correlation coefficient greater than 0.80 generally indicates good to very good simulation results. Coefficients for mean monthly flows at the three gages are in the range of 0.63 to 0.67, and thus the simulation of monthly runoff volumes can only be considered fair to poor on this basis.

Figure 5.4 compares simulated and observed mean daily flows for 1974 at Rowan, Marshalltown, and Marengo. While a better fit between simulated and observed results was obtained for several of the gages during other portions of the simulation period, the 1974 results were selected to illustrate several points. Timing discrepancies between simulated and observed flows are evident at all three gage sites and result from superimposing the timing of rainfall at one weather station onto large areas of land which experience variable timing of rainfall. Such problems with timing preclude the accurate modeling of individual flow events, but do not preclude simulation of reasonable annual water balances.



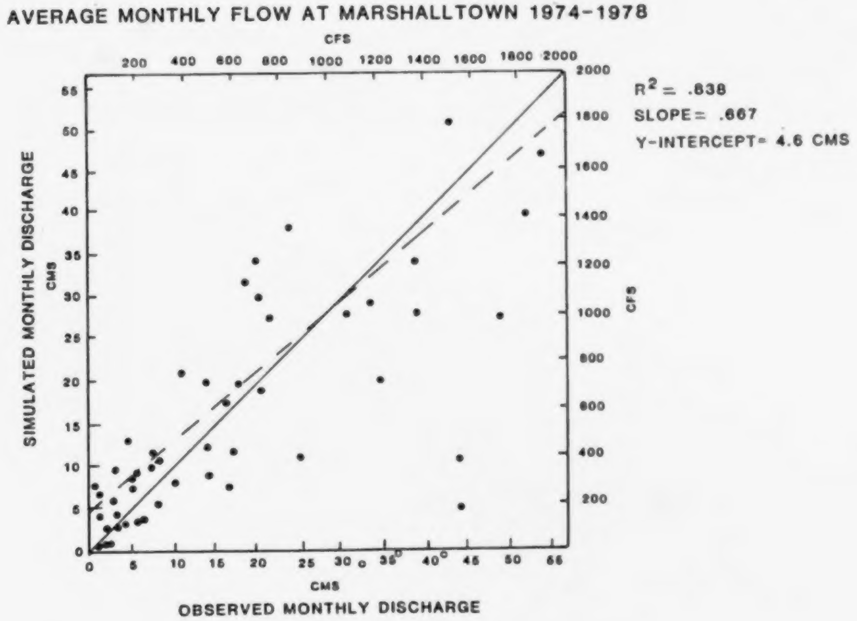


Figure 5.3 Mean monthly flow scattergrams at Rowan, Marshalltown, and Marengo, Iowa.

(continued)

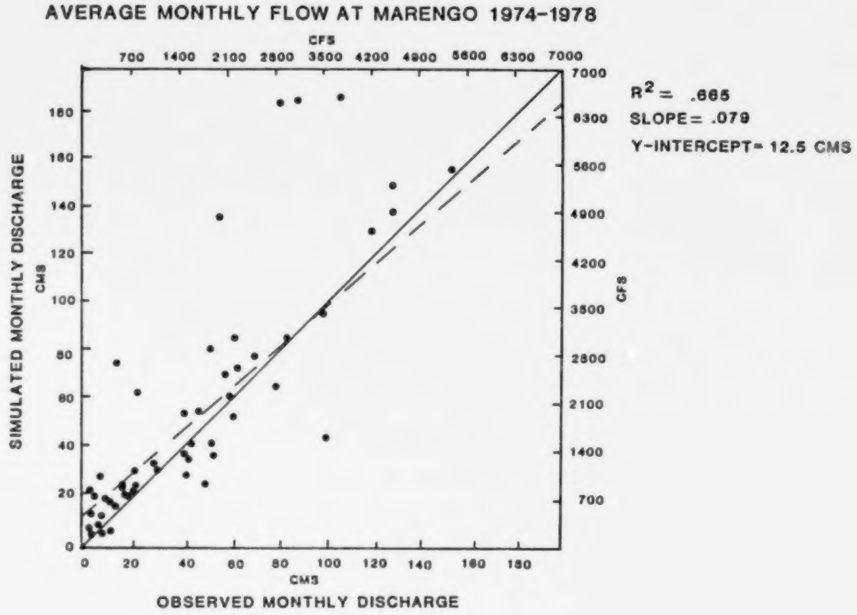


Figure 5.3 (continued).

TABLE 5.3 STATISTICS FROM REGRESSION ANALYSES OF OBSERVED AND SIMULATED STREAMFLOW FOR THE 1974-1978 PERIOD (BEST FIT LINE CALCULATED BY LEAST-SQUARES METHOD)

Rowan

	Slope	y-intercept(cms)	R
Mean Daily Flows	0.63	+2.6	0.16
3-Day Average Flows	0.70	+2.4	0.34
Mean Monthly Flows	0.85	+1.9	0.63

Marshalltown

	Slope	y-intercept(cms)	R
Mean Daily Flows	0.66	+8.6	0.28
3-Day Average Flows	0.72	+7.2	0.39
Mean Monthly Flows	0.84	+4.6	0.67

Marengo

	Slope	y-intercept(cms)	R
Mean Daily Flows	0.63	+24.2	0.34
3-Day Average Flows	0.65	+22.9	0.41
Mean Monthly Flows	0.87	+12.5	0.66

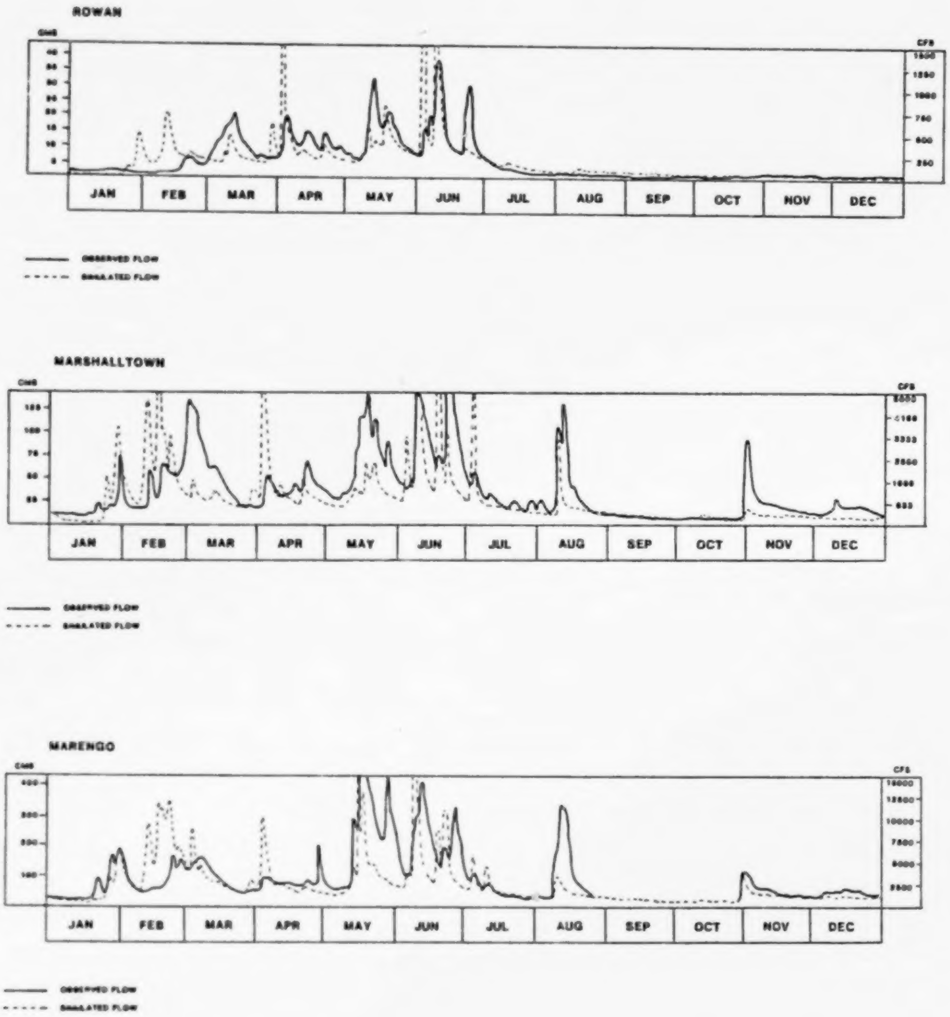


Figure 5.4 Comparison of simulated and observed hydrographs at Rowan, Marshalltown, and Marengo, Iowa.

A more serious problem is illustrated by the August storm in the middle and lower portions of the basin. In this case the recorded rainfall at the Iowa Falls and Traer stations is not nearly large enough to induce the 340 cms peak recorded at Marengo. Apparently, a major storm passed through the basin resulting in significant rainfall over large portions of the middle and lower basins while only a small amount of rainfall occurred at the weather stations used to represent the basin for simulation purposes.

For basin-scale modeling efforts lacking adequately representative meteorologic data, comparison of frequency information (i.e., simulated vs. observed flow frequency) is a better measure of overall simulation accuracy than comparison of individual storm event data. Consequently, the primary goal of the Iowa River simulation was accurate reproduction of observed flow frequencies. Figure 5.5 shows the simulated and observed daily flow frequencies for the 1974-1978 period at Rowan, Marshalltown, and Marengo. Of the three gages, the poorest results were produced at Rowan where adequate simulation of flows representing the mid-range of the frequency curve (0.5 - 7.0 cms) could not be achieved by adjustment of calibration parameters. All efforts to reduce the frequency of simulated flows in this range resulted in consistently unrealistic simulation of low flows. Given that the Rowan gage records runoff from only 15% of the basin, priority was given to producing the best fit possible at the two lower gages. Visual observation indicates that the simulated and observed flow frequency curves were matched reasonably well at both Marshalltown and Marengo. The goodness of fit was quantitatively evaluated using a statistical hypothesis testing method, the Kolmogorov-Smirnov (K-S) test of model simulations (Haan 1977). Though not a rigorous test, the K-S test provides an indication of overall agreement between two cumulative distributions and has been

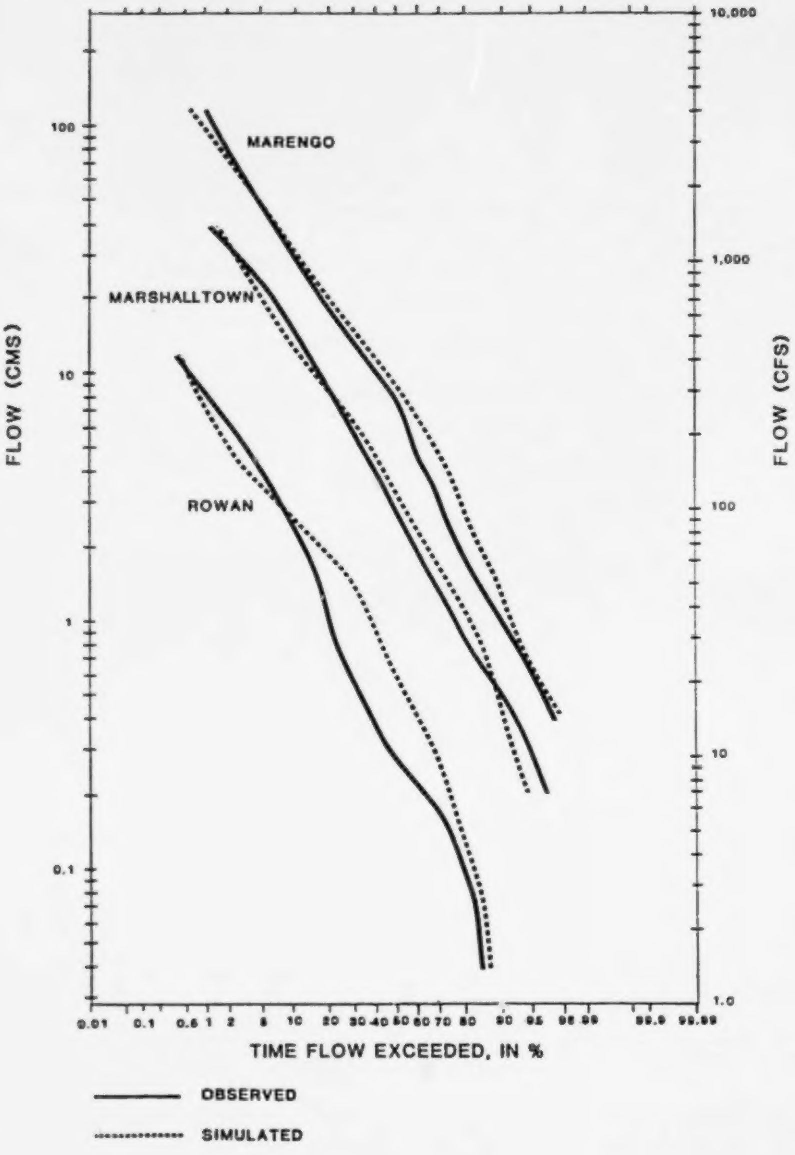


Figure 5.5 Comparison of simulated and observed flow frequencies at Rowan, Marshalltown, and Marengo, Iowa (1974-1978).

used in past modeling studies (Hartigan et al., 1982; Young and Alward, 1983). A basic assumption of the K-S test is that the data are independent of each other within a sample. In the case of daily streamflow, a value on any given day is strongly related to previous values. Autocorrelation analyses of each simulated and observed flow time series were conducted to determine the interval, k, such that every k^{th} observation out of the entire time series was considered a random sample. The results of the autocorrelation analyses indicated that, for the sample to be independent within the 95% confidence limit, the following intervals, K (in days), should be used:

Simulation Period
(1974-1978)

	simulated	observed
Rowan	92	81
Marshalltown	93	102
Marengo	113	110

The difference between the cumulative probability densities of the simulated and observed flows should not exceed a critical value, with a given significance level, in order to pass the test. The K-S test results are shown in Table 5.4 for the gages at Rowan, Marshalltown, and Marengo for the 1974-1978 simulation period. Streamflow simulation at all three gages passed the K-S test at the 10% significance level. These results are a confirmation of the validity of the Iowa River Basin.

TABLE 5.4 RESULTS OF K-S TESTS OF STREAMFLOW SIMULATION (1974-1978)

	Rowan		Marshalltown		Marengo	
Significance Level	D	Dmax	D	Dmax	D	Dmax
10%	0.38		0.41		0.43	
1%	0.51	0.222	0.54	0.06	0.58	0.19
0.1%	0.61		0.65		0.69	

The final hydrologic parameters for the nine pervious land segments are listed in Table 5.5. The annual ranges of monthly parameters are indicated. All parameters are given in English units.

5.3 SEDIMENT CALIBRATION AND VERIFICATION

The soil erosion and sediment transport calibration was performed in a manner analogous to the hydrologic modeling effort. First, overland sediment transport was simulated to provide edge-of-stream loadings. Estimates were made of gross erosion processes in the Iowa River area and then compared to simulated values for the various PLSs in order to achieve reasonable erosion rates. Second, instream sediment simulation was performed by adjusting channel sediment parameters to produce the best fit between simulated and observed daily sediment loadings at Marengo.

5.3.1 Edge-of-Stream Sediment Loadings

Detachment and removal of sediment from the basin were simulated based on input rainfall, simulation of overland flow, and input model parameter values describing the soil characteristics and land surface conditions. The following assumptions were made in representing erosion processes:

1. Gully erosion was not simulated.

2. Monthly fractions for erosion-related cover for corn fields, soybean fields, and pasture/other lands which

TABLE 5.5 FINAL CALIBRATION HYDROLOGY INPUT PARAMETER SET *

	Lower Segment Group			Middle Segment Group			Upper Segment Group		
	PLS 1 Beans	PLS 2 Corn	PLS 3 Other	PLS 4 Beans	PLS 5 Corn	PLS 6 Other	PLS 7 Beans	PLS 8 Corn	PLS 9 Other
LZSN	4.8	4.8	5.5	4.8	4.8	5.5	6.0	6.0	7.0
INFILT	0.025	0.025	0.04	0.025	0.025	0.04	0.04	0.04	0.055
LSUR	320.	320.	320.	300.	300.	300.	350.	350.	350.
SLSUR	0.02	0.02	0.03	0.03	0.03	0.04	0.01	0.01	0.01
KVARY	0.4	0.4	0.4	0.4	0.4	0.4	1.5	1.5	1.5
AGWRC	0.986	0.986	0.986	0.986	0.986	0.986	0.995	0.995	0.995
DEEPFR	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
BASETP	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
AGWETP	0.01	0.01	0.01	0.01	0.01	0.01	0.08	0.08	0.08
CEPSC**	0.03-0.16	0.05-0.18	0.06-0.1	0.03-0.16	0.05-0.18	0.06-0.1	0.03-0.16	0.05-0.18	0.06-0.1
UZSN**	0.3 -0.8	0.3 -0.7	0.5 -0.8	0.3 -0.8	0.3 -0.7	0.5 -0.8	0.4 -1.2	0.4 -7.0	0.8 -1.2
NSUR**	0.25-0.35	0.25-0.35	0.30	0.25-0.35	0.25-0.35	0.30	0.25-0.35	0.25-0.35	0.30
INTFW	0.7	0.7	0.9	0.7	0.7	0.9	0.7	0.7	0.9
IRC	0.7	0.7	0.8	0.7	0.7	0.8	0.55	0.55	0.65
LZEPT**	0.2 -0.7	0.2 -0.7	0.25-0.45	0.2 -0.7	0.2 -0.7	0.25-0.45	0.2 -0.7	0.2 -0.7	0.25-0.45

* PARAMETER VALUES ARE EXPRESSED IN ENGLISH UNITS. SEE HSPF USER MANUAL (JOHANSON ET AL., 1984) FOR UNITS.

** RANGE OF MONTHLY VALUES USED

were previously developed for the Four Mile Creek watershed were applied directly to the Iowa River Basin.

3. It was assumed that tillage practices, which significantly affect the availability of detached sediment, were uniform in all but timing for a given crop (corn or soybeans). Thus, soybean fields throughout the basin were assumed to be plowed, disked in early spring, and then cultivated for weed control twice in June and July each year. Corn fields were assumed to be plowed in November of each year, disked in April, and cultivated twice as for soybeans. It was assumed that all other land was not tilled.

4. The timing of agricultural practices for the lower third of the basin (segments 1, 2, 3) was assumed to be the same as the generalized timing of operations on the Four Mile Creek watershed:

Beans	Corn
plowing - 4/15	disking - 4/25
disking - 5/15	first cultivation - 6/11
first cultivation - 6/21	second cultivation - 7/1
second cultivation - 7/14	plowing - 11/15

For the middle portion of the basin (segments 4, 5, 6) spring and summer activities for soybeans and corn were assumed to occur one week later than in the lower basin, and the fall plowing on corn fields one week earlier. Tillage activities on the upper basin area (segments 7, 8, 9) followed a similar pattern, with two weeks variation from the lower basin.

As a first step in the 1983 Iowa River demonstration project, erosion parameter values developed in the Four Mile Creek Study (Donigian et al., 1983) were applied to the Iowa River Basin due to simularities in relevant soils characteristics. The simulated erosion from the basin was too low in the original Iowa River study; as a consequence, unrealistically high channel bed degradation was simulated in order to reproduce observed instream loadings at Marengo.

For the current study, erosion estimates from Four Mile Creek data (Johnson et al., 1978) and National Resources Inventory data for Iowa (USDA, 1982) were used to discern a reasonable range of erosion rates for the nine PLSs of the study area. Average annual gross erosion rates for croplands and pasture during a 5-year period from 1976-1980 in the Four Mile Creek test watersheds were approximately 16 Tonnes/Ha and .02 Tonnes/Ha, respectively. Corresponding long term values for the state of Iowa from the National Resources Inventory are 23 Tonnes/Ha for croplands and 6.2 Tonnes/Ha for pasture. The variability in estimates for pasture is due largely to the effects of slope on erosion rates.

Table 5.5 shows the final simulated erosion rates for the nine PLSs during the 1974-1978 simulation period. Simulated values are generally less than those estimated from the aforementioned data on gross erosion because only a fraction of the eroded soil actually reaches the stream channel. The values reported in Table 5.6 are actual sediment delivery, or edge-of-stream loadings from each PLS to the channel. Since delivery ratios in the Four Mile Creek area have been estimated on the order of 20% of total eroded soil, the average annual edge-of-stream erosion rates for croplands and pasture can be estimated for the 1976-1980 period of the Johnson data as 2.4 Tonnes/Ha and .004 Tonnes/Ha, respectively. Assuming a similar delivery ratio statewide, corresponding long term edge-of-stream loadings are 4.6

TABLE 5.6 SIMULATED SOIL EROSION RATES FOR THE NINE PLSs DURING THE 1974-1978 PERIOD

	Lower Segment Group			Middle Segment Group			Upper Segment Group		
	PLS 1 Beans	PLS 2 Corn	PLS 3 Other	PLS 4 Beans	PLS 5 Corn	PLS 6 Other	PLS 7 Beans	PLS 8 Corn	PLS 9 Other
Calibration									
1974	5.90	5.92	0.70	5.14	6.66	1.12	1.73	2.13	0.32
1975	2.30	2.78	0.58	2.10	2.40	0.41	0.67	0.84	0.05
1976(1/1-6/30)	0.85	1.09	0.28	0.88	0.92	0.28	0.03	0.03	0.00
Verification									
1976(7/1-12/31)	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
1977	1.75	1.76	0.28	0.54	0.56	0.09	0.34	0.56	0.22
1978	7.62	6.63	1.68	2.51	2.82	0.90	3.26	4.13	1.26
Average	3.68	3.64	0.70	2.23	2.67	0.56	1.21	1.54	0.37

Tonnes/Ha and 1.2 Tonnes/Ha, respectively. During a higher-than-normal flow year (1974) areal average simulated edge-of-stream loadings for the basin were 5.02 Tonnes /Ha for croplands and 0.8 Tonnes/Ha for pasture; during a year (1976) of lower-than-normal streamflow, corresponding loadings of 0.7 and 0.2 Tonnes/Ha were simulated. Since the simulated sediment erosion rates compare favorably with existing estimates for the area, the land surface simulation was considered acceptable, and attention was focused on the instream sediment simulation.

5.3.2 Instream Sediment Simulation

Simulation of instream sediment transport processes was performed based on inflow of sediment from upstream reaches, loadings from tributary land segments, exchange of sediments between the bed and suspension, and resulting outflow to downstream reaches. Since transport characteristics of sediment vary significantly with particle size, the three components of sediment (sand, silt, and clay) were simulated individually, and the results were summed for comparison with observed sediment loadings.

Data on bed depth composition were not available for the Iowa River. Consequently, assumed bed depths were assigned to the 13 river reaches, and bed core sample data collected by Iowa State University at nearby Four Mile Creek were used to approximate bed composition. Initial bed depth varied from 0.9 m in the upper reach to 3.0 m at Marengo. The beds of the lower three reaches were characterized as 60% sand, 20% silt, and 20% clay. Bed composition in the upper 10 reaches was initialized at 50% sand, 25% silt, and 25% clay.

It was necessary to divide the total edge-of-stream loadings of sediment into sand, silt and clay as input for instream simulation. Data collected by ISU for selected storms in the nearby Four Mile Creek watershed (Johnson, 1978), were used to approximate the particle size distribution for washoff from the lower third (segments 1, 2, 3) of the Iowa River Basin. Analysis of load-weighted particle size distribution curves indicated only a small amount of sand in sediment loadings from storm washoff from the Tama-Muscatine soils predominant in both Four Mile Creek and the bottom third of the study basin. Between 50 and 65% of measured sediment loading was silt, and 35% to 50% was clay.

Particle size distribution for the middle (segments 4, 5, 6) and upper (segments 7, 8, 9) portions of the Iowa River Basin was based on information presented by Davidson et al., (1978). Clarion and Webster soils predominate in these areas and are characterized by somewhat higher sand content and lower silt content. For all pasture lands, regardless of predominant soils type, it was assumed that sand particles are trapped in vegetation and do not run off. The assumed composition of sediment in runoff from soybeans, corn, and pasture is summarized below.

		Runoff Sediment Composition		
HSPF Segment	Land Type	% Sand	% Silt	% Clay
bottom segments				
PLS 1	soybeans	5	55	40
PLS 2	corn	5	55	40
PLS 3	pasture	0	60	40
middle segments				
PLS 4	soybeans	10	50	40
PLS 5	corn	10	50	40
PLS 6	pasture	0	60	40

upper segments				
PLS 7	soybeans	10	50	40
PLS 8	corn	10	50	40
PLS 9	pasture	0	60	40

In the 1983 demonstration study only an approximate calibration of sediment was performed. As a first step, instream sediment transport parameters developed for nearby Four Mile Creek were applied to the Iowa River. Three additional computer runs were made to adjust these parameters until a reasonable fit to recorded data for one simulation year (1974) was achieved. For the current study, the calibration period was expanded to two and one-half years (1974-June 1976), and additional adjustment of calibration parameters was performed to achieve best fit of simulated and observed daily sediment loadings at Marengo.

Table 5.7 provides a summary of simulated and observed sediment loadings for both the calibration and verification periods. While results for the calibration period are quite good, there was a significant discrepancy between simulated and observed totals for the 1978 portion of the verification period. However, oversimulation during this year can be attributed to parallel oversimulation of flow. For the entire simulation period, simulated sediment loadings at Marengo exceeded observed loadings by 49%. If the 1978 simulation had been on target, an oversimulation of only 18% would have been produced for the 5-year period. In general, simulated annual total sediment loadings for the basin were quite adequate.

Figure 5.6 shows observed and simulated sediment concentration frequency curves at Marengo for the entire simulation period. The overall fit was good; in fact, the only significant discrepancy between the curves was in the frequency of

TABLE 5.7 SUMMARY OF SIMULATED AND OBSERVED SEDIMENT LOADINGS AT MARENGO, IOWA (TONNES/Ha)

	SIM LAND SURFACE	SIM STREAM CHANNEL	TOTAL SIM LOADINGS	TOTAL OBS LOADINGS	DIF (%)
Calibration Year					
1974	3.61	0.88	4.50	4.05	+ 11
1975	1.53	0.74	2.27	1.50	+ 51
1976 (1/1-6/30)	0.57	0.45	1.02	1.21	- 15
Verification Year					
1976 (7/1-12/31)	0.00	0.00	0.00	0.03	-
1977	0.74	0.16	0.90	0.33	+174
1978 (1/1-9/30)	3.43	1.15	4.58	1.80	+154
Total...	9.88	3.38	13.27	8.92	+ 49

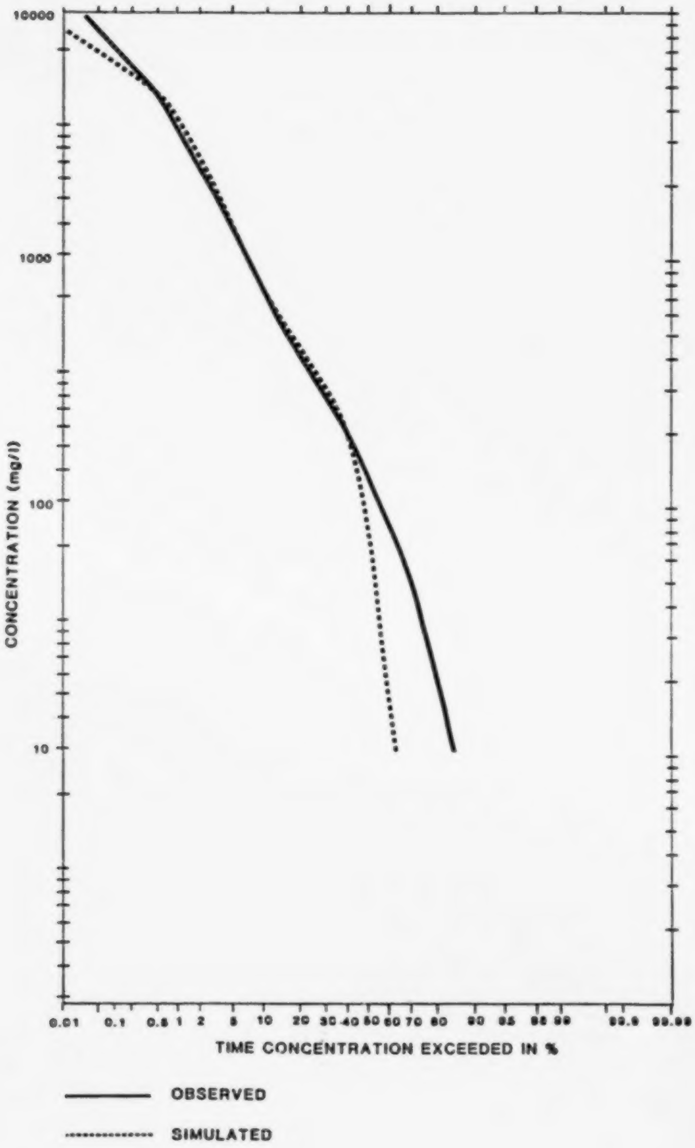


Figure 5.6 Comparison of simulated and observed instream sediment concentrations at Marengo, Iowa.

concentrations below the 100 mg/l level. Comparison of simulated sediment concentrations with simulated loadings presents an interesting observation. Loadings for the 5-year period were oversimulated by 49%, and for the same period sediment concentrations were somewhat undersimulated as evidenced by Figure 5.6. This apparent discrepancy can be explained by the 11% oversimulation of flow at Marengo which in effect serves to dilute the simulated sediment concentrations.

In the 1983 demonstration project, simulation of the channel bed produced unrealistic results. Drastic degradation occurred in the majority of the channel reaches, and the clay fraction in 11 of the 13 reach beds was totally eroded. Results of the current simulation were much more reasonable. The upper reaches with low channel slope showed gradual aggradation over the 5-year simulation; middle reaches with greater slopes showed degradation in the range of 22 to 26 cm; and the far downstream reaches with low slope showed degradation at a reduced level of approximately 9 cm for the 5-year period. Sand, silt and clay were present in all reach beds at the end of the simulation period. While geomorphological data concerning the aggradation/degradation of the Iowa River channel were not available, data from nearby Four Mile Creek (Hamlett et al., 1983) indicate a degrading channel with 25 to 50% of total sediment yield contributed by channel erosion. Calibration period results for the Iowa River showed an average of 27% contribution to total sediment yield resulting from channel erosion. Based on these analyses, the bed behavior during the simulation period appeared reasonable. Overall, sediment simulation in the Iowa River Basin was quite successful within the constraints created by the flow simulation problems.

The final sets of sediment parameters are listed in Table 5.8

TABLE 5.8 FINAL CALIBRATION LAND SURFACE SOIL EROSION INPUT PARAMETER SET*

Parameter	Lower Segment Group PLS 1 Beans	 PLS 2 Corn	 PLS 3 Other	Middle Segment Group PLS 4 Beans	 PLS 5 Corn	 PLS 6 Other	Upper Segment Group PLS 7 Beans	 PLS 8 Corn	 PLS 9 Other
KRER	0.45	0.45	0.40	0.45	0.45	0.40	0.40	0.40	0.35
JRER	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2	2.2
AFFIX	0.03	0.03	0.003	0.03	0.03	0.003	0.03	0.03	0.003
COVER	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
KSER	4.0	3.5	3.0	4.0	3.5	3.0	4.0	3.5	3.0
JSER	2.0	1.9	1.8	2.0	1.9	1.8	2.0	1.9	1.8
KGER	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
JGER	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
DETS**	1.2/ 2.0/ 1.5	2.0/ 1.5	0.1	1.2/ 2.0/ 1.5	2.0/ 1.5	0.1	1.2/ 2.0/ 1.5	2.0/ 1.5	0.1

* PARAMETER VALUES ARE EXPRESSED IN ENGLISH UNITS. SEE HSPF USER MANUAL(JOHANSON ET AL., 1984)FOR UNITS

** VALUES SHOWN FOR BEAN SEGMENTS ARE FOR PLOWING/DISKING/CULTIVATION, RESPECTIVELY. VALUES SHOWN FOR CORN SEGMENTS ARE FOR DISKING/CULTIVATION, RESPECTIVELY.

for the land surface and Table 5.9 for the reach system. The annual ranges of monthly parameters are shown. All parameter values are given in English units.

TABLE 5.9 FINAL CALIBRATION CHANNEL SEDIMENT TRANSPORT INPUT PARAMETER SET *

Parameter	Value		
	Sand	Silt	Clay
D	0.014	0.00063	0.000055
W	1.5	0.003	0.000022
RHO	2.65	2.2	2.0
TAUCD	-	0.03	0.02
TAUCS	-	0.07	0.05
M	-	0.03	0.045

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* THE SAME PARAMETER VALUES WERE USED FOR ALL 13 REACHES; ENGLISH UNITS ARE USED. SEE HSPF USER MANUAL (JOHANSON ET AL., 1984) FOR UNITS.

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APPENDIX K

Turkey Creek, Nebraska

Watershed Data, Segmentation, and HSPF Calibration/Verification Report (Incomplete)

ABSTRACT

The EPA Hydrological Simulation Program - FORTRAN (HSPF) was applied to the Turkey Creek Watershed near Lincoln, NE, as part of the development of a methodology to estimate pesticide runoff and resulting instream concentrations from agricultural cropland in various regions of the United States. Turkey Creek was chosen as representative of watersheds in the Central Plains region. HSPF was to be calibrated and verified for hydrology, hydraulics, sediment erosion, and instream sediment transport as a basis for performing sensitivity analyses on key pesticide parameters.

This report describes the watershed data available for simulation and the segmentation plan for dividing the study area into land and channel segments. Calibration and verification efforts were not completed.

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Ms. Carol McCullough directed the final preparation of the document with text editing performed by Ms. Arinthia L. Jones and with figures and charts prepared by Ms. Marythomas Hutchins.

SECTION 1

INTRODUCTION AND EXECUTIVE SUMMARY

The application of HSPF to the Turkey Creek Basin was undertaken as part of the parent study, described in the body of this report, to develop procedures for estimating the likely magnitude and variability of instream pesticide concentrations and pesticide runoff from cropland in selected agricultural regions of the U.S. The overall approach was to evaluate the characteristics of "representative" agricultural watersheds within each region, perform sensitivity analyses using HSPF for a range of selected chemical properties, and transform the model results into a series of curves for estimating (1) the frequency and duration of pesticide concentrations at a watershed outlet, and (2) pesticide runoff from the associated cropland; to use the curves the only information needed is chemical properties and the chemical application rate. To provide a sound basis for the methodology HSPF was applied to actual watersheds within each agricultural region as a demonstration of its ability to simulate chemical transport processes on agricultural watersheds throughout the country. The Turkey Creek Basin was selected as the HSPF application site within the Central Plains Region.

1.1 STUDY OBJECTIVES

Within the framework of the study described above, the objectives of the HSPF application to the Turkey Creek Basin were as follows:

a. demonstrate the ability of HSPF to model the hydrologic, hydraulic, sediment erosion, and sediment transport behavior of an agricultural watershed characteristic of the Central Plains Region;

b. estimate selected model parameters, which are usually evaluated through calibration, as a basis for determining representative parameter values for the region.

Pesticide simulation was not performed as part of this application due to the lack of observed pesticide data for comparison with model results and lack of adequate project resources; however, previous studies with HSPF (Donigian et al., 1983) and with predecessor models (Donigian et al., 1977) have sufficiently confirmed the pesticide simulation capabilities of HSPF for the purposes of this project.

The Turkey Creek Basin was selected as an application site because of its location in the Central Plains Region, its agricultural land, previous modeling studies, and the availability of a reasonably adequate data base for model application.

The pesticide assessment methodology developed in the parent study provides a screening-level type analysis with order-of-magnitude accuracy in its predictions. Consequently, a

greater degree of latitude was possible in the needed accuracy of the HSPF calibration than would have been allowable for more detailed and demanding planning, design, or watershed management purposes. Also, resource limitations required restrictions on the level of calibration. However, the model results are consistent with and well suited to the overall objectives and framework of this study.

1.2 REPORT CONTENT AND ORGANIZATION

The remainder of this introductory section provides an overall summary of the results of the HSPF application to the Turkey Creek Basin, followed by conclusions and recommendations for future improvements in the simulation. The body of this appendix begins with the watershed and study area descriptions in Section 2, and the discussion of available data for modeling in Section 3. Section 4 describes the HSPF representation of the watershed through segmentation of the land area, based on meteorologic, edaphic, and land use characteristics, and segmentation of the stream channel. At this time, calibration and verification could not be completed. This report contains all information required preliminary to the actual model application.

SECTION 2

WATERSHED DESCRIPTION

2.1 LOCATION, SIZE, AND SURFACE PHYSIOGRAPHY

The Turkey Creek watershed (Figure 2.1) lies in the southeast section of the state of Nebraska and covers an area of 1191 sq. km (460 sq. mi.). The main channel of the creek stretches 133.2 km (82.8 mi.) through very level to gently rolling farmland. The watershed is 77 km (48 mi.) long and between 12 and 19 km (8-12 mi.) wide, beginning in Clay Co., passing through Fillmore Co., and ending in Saline Co. The creek flows from west to east and is joined by many small and intermittently flowing drainage channels.

There is one USGS streamgage located near Wilber on Turkey Creek. The gage is positioned 32 km (20 mi.) upstream of the confluence with the Big Blue River, which eventually flows into the Kansas River in northeastern Kansas. One meteorologic recording station (at Friend) exists on the north-central boundary of the drainage basin, while two others (Crete and Fairmont) lie just north of the watershed at the eastern and western extremes. The locations are identified on Figure 2.1.

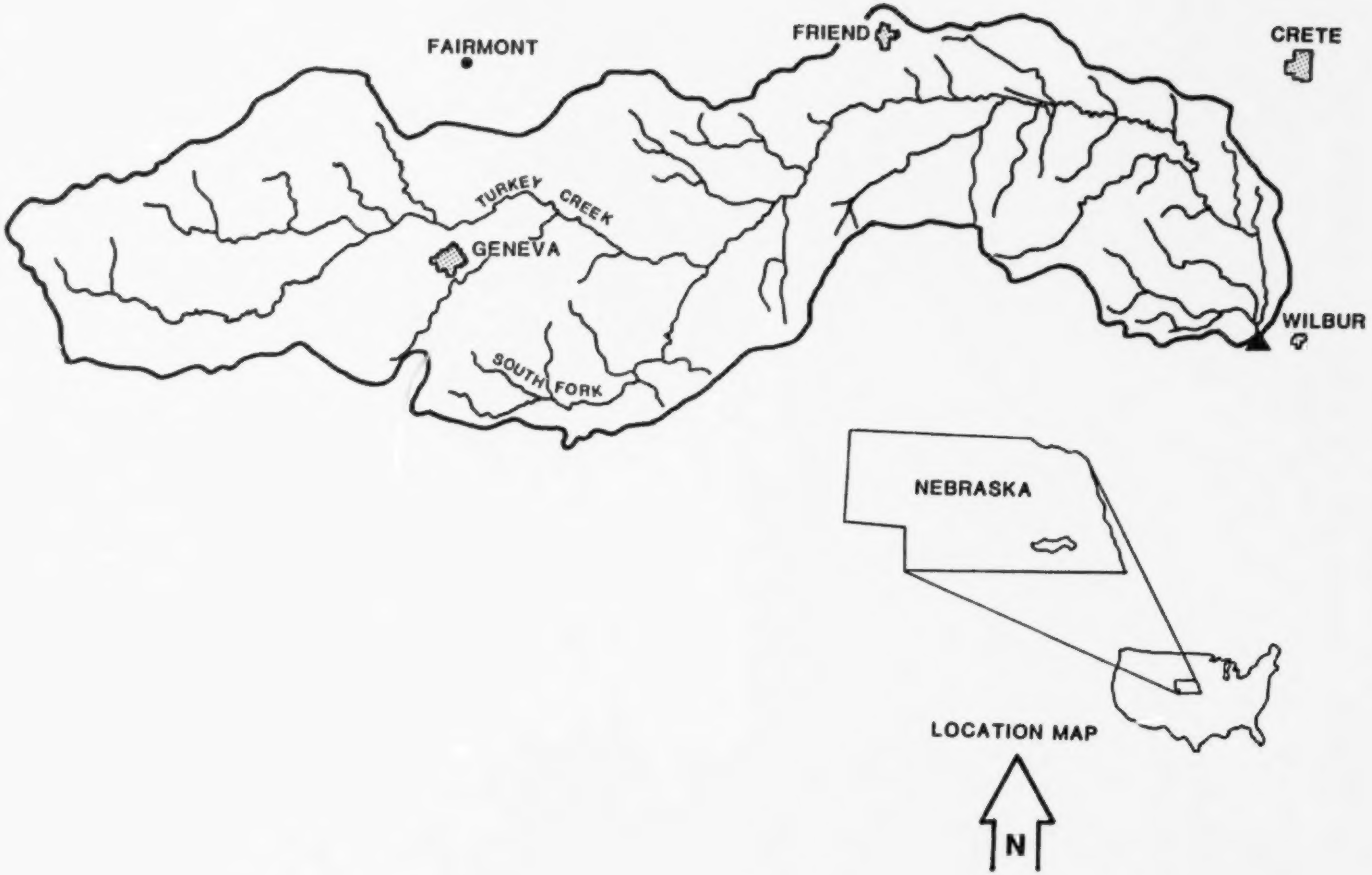

FAIRMONT
FRIEND
CRETE
TURKEY CREEK
GENEVA
SOUTH FORK
WILBUR
NEBRASKA
LOCATION MAP
N

Figure 2.1 Turkey Creek Basin location map.

The Turkey Creek drainage basin is long and narrow. The western half of the basin is extremely flat and the drainage channels, along with the main-stream, flow intermittently throughout the summer and fall. In the middle of the watershed the land develops into a gently rolling terrain, which becomes more pronounced to the east. At this point Turkey Creek becomes a perrenial stream, due in most part to ground-water base flow developing in the surrounding higher elevations. The high point of the watershed lies on the western extreme at 533 m (1750 ft) above mean sea level, the low point at 403 m (1322 ft). The stream channel slope remains almost constant throughout its length, watershed elevation changes more as the streamgage is approached. Mean daily discharge at the gage is 2.17 cms (76.7 cfs), with the bulk of flow produced during spring snowmelt. Occasional high intensity spring or summer thunderstorms can provide substantial amounts of runoff. One such storm in the spring of 1984 produced an estimated flow at the gage of 935 cms (33,000 cfs). Previous to this flood the maximum recorded discharge had been 207 cms (7300 cfs) in 1960.

2.2 CLIMATE

The climate of Turkey Creek is sub-humid continental and typical of the Central Plains region. It is characterized by wide variations in temperature between winter and summer (-36 deg. C to 47 deg. C). Cold winter systems travel from the north across the continent. Cool periods in the summer also follow this pattern. Summers are generally hot and humid. Average daily temperatures for the entire year range from 10.7 deg. C (51.3 deg. F) in the west to 11.1 deg. C (52.0 deg. F) in the east. Daily average winter temperatures remain below freezing. Average annual precipitation ranges from 68.6 cm (27 in.) in the west to 73.7 cm (29 in.) in the east. More than half of the annual rainfall is from thunderstorms during May, June, July and August (Lower Big Blue Natural Resources District, 1978). Light rains throughout the spring favor land preparation for agriculture, but late-spring storms cause potential erosion problems when land is cultivated. Thunderstorms occur on approximately 50 days out of the year, most of them in the summer (Hammer et al., 1981). Because of the large influence of thunderstorms on total annual precipitation, rainfall volumes from year to year vary dramatically. Variability in summer precipitation is nearly twice that of the Eastern Cornbelt (USDA, 1967). Annual rainfall is well distributed as relates to the growing season, but monthly distribution within the season is poor. As a result, little precipitation has been recorded in some months while others have received as much as 40.6 cm (16 in.) (Nebraska Soil and Water Conservation Commission, 1968).

Precipitation occurs primarily in the form of rain, but heavy snowfalls have been recorded. Average seasonal snowfall ranges between 56 and 86 cm (22-34 in.). Snowpack does not remain on the ground all season long. Snowfall occurs predominantly in December through March.

The growing season ranges from between 170-200 days with the last frost date around April 15 and the first killing frost around October 23.

Mean annual lake evaporation is approximately 114 cm (45 in.). The evaporation pan coefficient is .70 (U.S. Dept. of Commerce, 1968).

The prevailing wind during the winter is from the northwest and from the south for the rest of the year. Average windspeed is highest, 22.5 km/hr (14 mi./hr), in April (Hammer et al., 1981) and averages about 19 km/hr during the growing season. Severe dust storms occasionally occur in the spring, but tornados are uncommon.

The average relative humidity in mid-afternoon is about 60%. Humidity is higher at night, the average at dawn being 80%. The sun shines 70% of the time possible in summer and 60% in winter (Hammer et al., 1981).

2.3 SOILS, GEOLOGY, AND EROSION

Turkey Creek is located in the Central Great Plains Winter Wheat and Range Region and lies on the eastern boundary of the Central Loess Plains (75) Land Resource Area. Soils in the drainage basin consist, for the most part, of associations of the Hastings, Crete, and Butler groups. Surface drainage has been the dominant factor in the development of the upland soils in this area.

Hastings soils are predominant on well drained sites associated with gentle and rolling slopes. They are well-drained throughout and have a thick silt loam surface layer. The subsoil is silty clay loam. Hastings soil has developed from light grey loess material under conditions of good surface drainage and underdrainage (Hayes, 1931). The upper part of the subsoil is not sufficiently dense to restrict root development or the movement of soil moisture. Hastings soil is classified in hydrologic group B. Organic matter ranges between 2-4% in the upper layers. The lower part of the subsoil has received practically no organic material.

Crete soils occur on broad, nearly level upland areas. They were formed from grey loess similar to that underlying Hastings silt loam (Hayes, 1931). The topsoil of Crete silt loam is approximately 43 cm (17 in.) thick and very like that of Hastings silt loam. The upper part of the subsoil is mainly greyish-brown silty clay, the underlying material is calcareous silt loam. The silt clay layer ranges between 35 and 45 cm (14-18in.) thick and restricts both water and root penetration (Hayes, 1931). Crete silt loam belongs to hydrologic group D.

Butler soils are located in nearly level to slightly concave areas. The topsoil is similar to Hastings and Crete silt loams, although not as deep. The surface layer is greyish-brown silt loam. The subsoil is silty clay, and acts as a dense claypan identical to the Crete subsurface layer. Butler silt loam also belongs to hydrologic group D, because of the restrictive layer.

Alluvial soils consist, to a large extent, of highly productive silt loams and silty clay loams, with locally gravelly phases. They are subject to occasional or frequent flooding. Most of these soils are cultivated, although some areas are wooded. Table 2.1 provides information measured or estimated by the Soil Conservation Service for Fillmore and Clay Counties on the predominant soils of Turkey Creek.

Geologic formations of hydrologic importance include the most recent bedrocks and the Quaternary deposits of unconsolidated strata overlying them. The upper layers of bedrock do not provide an economical source of ground water, but do help to determine the depth of overlying deposits. The relief of the bedrock is somewhat greater than the present day surface (Keech and Dreeszen, 1968). As a result, one bedrock outcrop exists within the Turkey Creek basin, at the Fillmore/Saline

TABLE 2.1 PREDOMINANT SOIL CHARACTERISTICS (Source: SCS, 1981; SCS, UNPUBLISHED)

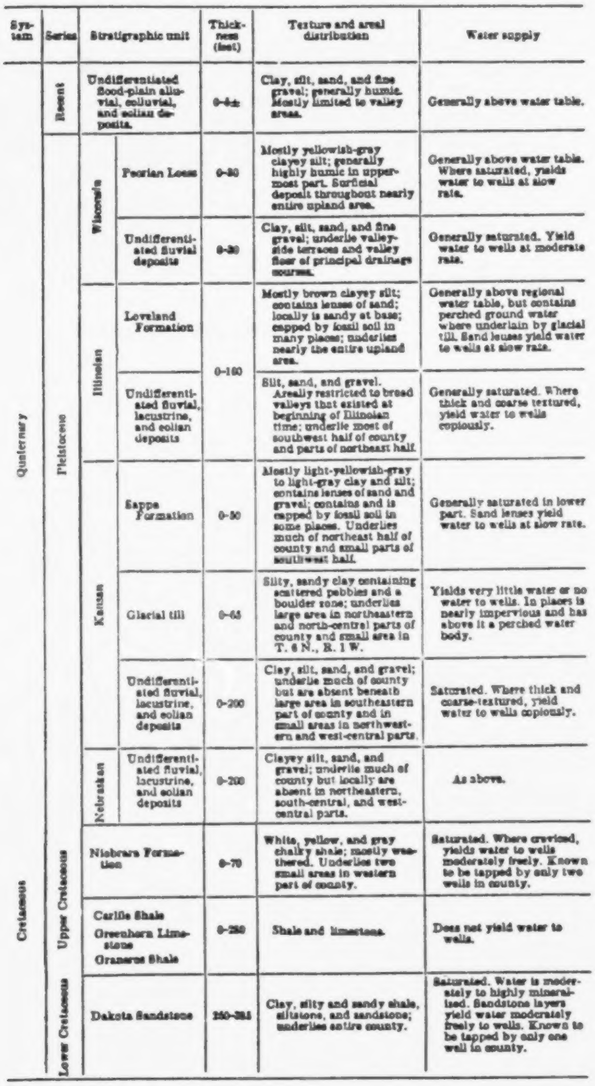
Soil	Sand %	Silt %	Clay %	Permeability cm/hr	Erodibility (K)	Organic Matter %
Hastings Silt Loam						
Surface	8	68	24	1.5-5.1	.32	2-4
Sub-surface	6	36	58	0.5-1.5	.43	
Bottom	8	68	24	1.5-5.1	.43	
Crete Silt Loam						
Surface	7	65	28	1.5-5.1	.37	2-4
Sub-surface	5	38	57	0.2-1.5	.37	
Bottom	7	61	32	0.5-5.1	.37	
Butler Silt Loam						
Surface	2	71	27	1.5-5.1	.37	2-4
Sub-surface	5	45	50	0.2-0.5	.37	
Bottom	8	64	28	0.5-5.1	.37	

county border. Bedrock mounding also occurs at the Clay/Fillmore county border. In both of these cases, no water-bearing formation exists for economic water withdrawal. Nowhere in the basin do consolidated layers provide enough water for irrigation purposes.

The most important sources of good quality water are the unconsolidated layers of Quaternary deposits. These include both Pleistocene and recent sediments that are relatively unconsolidated, formed in layers of sand and gravel of high permeability (Nebraska Soil and Water Conservation Commission, 1968). Due to the relatively high relief of bedrock, the waterbearing layers range in thickness from 18.3 to 137.2 m (60-450 ft.) (Keech and Dreeszen, 1968). It is generally agreed that during the Pleistocene age, four glaciated periods existed to varying extents in the Turkey Creek area. The resulting deposits vary in thickness across the basin. Generally, the deposits are thicker in the east and thinner to the west. In the "bedrock high" areas, a thin layer of sand and gravel mantles their crests, providing time-variable water sources, depending on local rainfall activity. Table 2.2 provides a generalized discription of the geologic formations in the Turkey Creek area.

Approximately 15% of the Turkey Creek drainage basin has the potential for erosion hazard, as compiled by the Soil Conservation Service (USDA, 1977). This potential amounts to between 11.2-33.6 Tonnes/Ha (5-15 Tons/Ac) and occurs on hillside breaks only (Dick Hayes, SCS, personal communication, 1984). Moderate gully erosion may occur on slopes greater than 2%. Few large gullies develop each year that require substantial restructuring of hillsides to make cultivation possible again (Mike Raabe, SCS, personal communication, 1984). Sheet and rill erosion produce approximately 90% of the total delivered sediment to the stream system (Scott

TABLE 2.2 GENERALIZED DESCRIPTION OF THE GEOLOGIC FORMATIONS OF CRETACEOUS AND QUATERNARY AGE AND THEIR WATER-BEARING CHARACTERISTICS (Source: Keetch and Dreeszen, 1968)



System	Series	Stratigraphic unit		Thickness (feet)	Texture and areal distribution	Water supply
Quaternary	Recent	Undifferentiated flood-plain alluvial, colluvial, and eolian deposits.		0-6±	Clay, silt, sand, and fine gravel; generally humic. Mostly limited to valley areas.	Generally above water table.
	Pleistocene	Wisconsin	Peorian Loess	0-80	Mostly yellowish-gray clayey silt; generally highly humic in uppermost part. Surficial deposit throughout nearly entire upland area.	Generally above water table. Where saturated, yields water to wells at slow rate.
			Undifferentiated fluvial deposits	0-20	Clay, silt, sand, and fine gravel; underlie valley-side terraces and valley floor of principal drainage courses.	Generally saturated. Yield water to wells at moderate rate.
		Illinoian	Loveland Formation	0-180	Mostly brown clayey silt; contains lenses of sand; locally is sandy at base; capped by fossil soil in many places; underlies nearly the entire upland area.	Generally above regional water table, but contains perched ground water where underlain by glacial till. Sand lenses yield water to wells at slow rate.
			Undifferentiated fluvial, lacustrine, and eolian deposits		Silt, sand, and gravel. Areally restricted to broad valleys that existed at beginning of Illinoian time; underlie most of southwest half of county and parts of northeast half.	Generally saturated. Where thick and coarse textured, yield water to wells copiously.
		Kansan	Sappa Formation	0-50	Mostly light-yellowish-gray to light-gray clay and silt; contains lenses of sand and gravel; contains and is capped by fossil soil in some places. Underlies much of northeast half of county and small parts of southwest half.	Generally saturated in lower part. Sand lenses yield water to wells at slow rate.
			Glacial till	0-65	Silty, sandy clay containing scattered pebbles and a boulder zone; underlies large area in northeastern and north-central parts of county and small area in T. 6 N., R. 1 W.	Yields very little water or no water to wells. In places is nearly impervious and has above it a perched water body.
			Undifferentiated fluvial, lacustrine, and eolian deposits	0-200	Clay, silt, sand, and gravel; underlie much of county but are absent beneath large area in southeastern part of county and in small areas in northwestern and west-central parts.	Saturated. Where thick and coarse-textured, yield water to wells copiously.
		Nebraskan	Undifferentiated fluvial, lacustrine, and eolian deposits	0-200	Clayey silt, sand, and gravel; underlie much of county but locally are absent in northeastern, south-central, and west-central parts.	As above.
Cretaceous	Upper Cretaceous	Niobrara Formation		0-70	White, yellow, and gray chalky shale; mostly weathered. Underlies two small areas in western part of county.	Saturated. Where creviced, yields water to wells moderately freely. Known to be tapped by only two wells in county.
		Carlile Shale Greenhorn Limestone Graneros Shale		0-250	Shale and limestone.	Does not yield water to wells.
	Lower Cretaceous	Dakota Sandstone		250-385	Clay, silty and sandy shale, siltstone, and sandstone; underlies entire county.	Saturated. Water is moderately to highly mineralized. Sandstone layers yield water moderately freely to wells. Known to be tapped by only one well in county.

Scumshon, SCS, personal communication, 1984). Sheet and rill erosion is minimized by conservation tillage practices. In Clay County approximately 60% of the farmers practice conservation tillage by leaving 20% crop residue on the surface soil following harvest. The same percentage of farmers throughout the Turkey Creek Basin can be assumed to follow this practice, resulting in a 50% reduction of potentially eroded soil on their land. Attaining 20% crop residue may be difficult on steeper slopes where crop density is relatively low. This results in higher erosion rates from land in close proximity to watercourses. Fortunately, this occurs on only about 3% of the land, but it does provide a mechanism for substantial sediment delivery (USDA, 1967).

2.4 LAND USES AND MANAGEMENT

Approximately 95% of the Turkey Creek Basin is devoted to agriculture. The remaining 5% consists of urban, roads, and water surface areas. Table 2.3 provides a breakdown of major land uses for land units including or included in the Turkey Creek Basin. Land use components specific to Turkey Creek were chosen by synthesizing this information and compensating for peculiarities of the study area.

2.4.1 Agricultural Crops

The major agricultural crops grown in the basin are corn, sorghum (milo), winter wheat, soybeans, and alfalfa. The mix of crops has changed drastically over the past 35 years, due in most part to the development of irrigation. This is true of the ten year simulation period chosen for this watershed

TABLE 2.3 LAND USE BREAKDOWN

Location	Percent Land Cover			
	Cropland	Pasture/Range	Trees	Other
Land Resource Area 75[1]	78	14	1	7
Big Blue River Basin[2]	79	11	5	5
Little Blue River Basin[2]	68	21	8	3
Big Blue River Basin (LRA 75)[3]	82	10	1	7
Swan Creek[4]	76	18	2	4
Saline County[5]	79	12	3	6
Fillmore County[6]	87	9	1	3
Clay County[7]	81	12	1	6
Turkey Creek Basin[8]	80	20	0	0

---

[1] SCS, unpublished.
[2] Nebraska Natural Resource Commission, 1983.
[3] U.S. Dept. of Agriculture, 1967.
[4] Lower Big Blue Resource District, 1982.
[5] Saline County SCS Office, personal communication, 1984.
[6] Fillmore County SCS Office, personal communication, 1984.
[7] Hammer et al., 1981.
[8] All non-cropland was combined into the pasture category for simulation purposes.

(1972-1981). During this period soybeans were introduced and corn developed into the major cash crop, while winter wheat declined in its stead. The crops can be divided into two groups; those irrigated and those not. Corn and soybeans are mostly irrigated. Sorghum and wheat are mostly dryland farmed. All crops are grown uniformly throughout the basin, but due to the relatively steep terrain and the diminished availability of irrigation water, dryland farming is more prevalent in the east. Current estimates of crop distribution must be adjusted to account for development as a result of increased irrigation.

2.4.1.1 Corn--

Prior to development of irrigation practices, corn was dryland farmed, resulting in erratic productivity from year to year. As mentioned in Section 2.2, rainfall is well distributed over the growing season as a whole, but monthly distribution within the season is poor. With the advent of irrigation, through development of deep ground-water well systems, corn has replaced wheat, which is still entirely dryland farmed.

Traditionally, corn, sorghum, wheat, and alfalfa have been rotated in various combinations from year to year. As increased farming costs have forced small farms out of business, the resulting large farms are required to maximize profits over the short term. New equipment, capable of working the larger acreage, bought under high interest rates, has forced the growing farmer to maintain cash crops each year. In the western half of the Turkey Creek Basin this has been the trend over the last ten years (Mike Raabe, personal communication, 1984). The eastern half of the basin is generally farmed by traditional methods where crop rotation is maintained and corn is not the major crop.

Approximately 30% of corn acreage is plowed or disced in the fall after harvest. Close to 40% of the acreage will have 20% or more ground cover after planting (Gary Wooten, AES, personal communication, 1984). Table 2.4 shows a typical sequence of tillage operations for corn.

2.4.1.2 Soybeans--

Soybeans were nearly non-existent ten years ago in the Turkey Creek Basin. With the advent of irrigation and increased market price, soybeans now comprise approximately 15% of total cropland acreage. For the purposes of this study, soybeans will be lumped with corn as an irrigated crop even though a larger percent of beans are dryland farmed. Soybeans and corn follow similiar planting and tillage practices although plant development and spacing are not necessarily similar. Because soybeans played a minor role as a crop component during the study period, no attempt was made to account for it by altering crop management related parameters in HSPF.

2.4.1.3 Sorghum--

Sorghum, or milo as it is locally called, has been maintained at a constant level of planted acreage in spite of the development of irrigation throughout the region. For the most part, sorghum is dryland farmed. Whereas corn is increasingly planted year after year on the same ground, sorghum and beans are generally rotated. A typical rotation includes 2 years of sorghum, 1 year soybeans, and 1 year winter wheat. If sorghum follows wheat, the land is normally plowed during the previous summer, providing little or no ground cover by planting time. If sorghum follows sorghum or corn there will normally be around 20% residue left by planting time (Gary Wooten, AES, personal communication, 1984). The typical sequence of tillage operations for sorghum appears in Table 2.4.

TABLE 2.4 TYPICAL TILLAGE PRACTICES FOR MAJOR CROPS IN THE TURKEY CREEK BASIN

Month	Corn	Sorghum	Wheat
Jan			
Feb			
Mar			
Apr	Bed Preparation Disking	Bed Preparation	
May	Plant Cultivate	Disking Plant	
Jun	Cultivate	Cultivate	
Jul		Cultivate	Harvest
Aug			Plow
Sep			Plant
Oct	Harvest	Harvest	
Nov	Light Disk	Light Disk	
Dec			

2.4.1.4 Winter Wheat--

Winter wheat is always dryland farmed. Due to increased irrigation development, wheat acreage has increasingly been turned into corn and soybeans. These crops bring in higher revenues as ground water for irrigation has remained relatively inexpensive. In the eastern half of the Turkey Creek Basin, ground water cannot be accessed over large areas, resulting in an emphasis on dryland farming practices to this day. During the study period, winter wheat played a dominant role in crop production activity throughout the basin. Over the last ten years, wheat acreage has declined an estimated 50% in Fillmore County (Carl Connaly, SCS, personal communication, 1984). The typical sequence of tillage operations for winter wheat appears in Table 2.4.

2.4.1.5 Other Crops--

No other crops are grown in substantial amounts except for alfalfa and other hays. These are dryland farmed and make up less than five percent of the remaining cropland. For the purposes of this study, hay acreage will be treated as pastured land.

During any year, between 5 and 10% of cropland may be left idle. Depending on the crop that preceded the idle period, as well as the location in the watershed, 0-50% residue will be left as ground cover. Generally, greater amounts of residue are maintained in the eastern half of the basin, due to the more traditional farming practices employed.

2.4.2 Forest

There are no forested areas within the Turkey Creek Basin. Trees have been planted as windbreaks and occur along the entire length of the creekbed. They cover an estimated one percent of land area within the basin. The trees become more abundant in the lower half of the watershed due to increased availability of perennial water.

2.4.3 Pasture

Pasture land makes up approximately 12% of the Turkey Creek Basin. A majority of existing grassland lies along the creek where livestock are often left to graze. Land in pasture is kept to a minimum so that crop production can be maximized. This has resulted in over-grazing problems that occur principally along streambanks. Erosion potential is thereby increased in a narrow strip of locally sensitive land.

2.4.4 Other Land Uses

Approximately five percent of the Turkey Creek Basin is covered by roads, building, and open water tracts. Small wetland habitats are maintained where irrigation return flow collection pits exist. These small basins are becoming more popular as more efficient recycling of water is developed.

2.5 WATER RESOURCES

Average annual precipitation ranges from 68.6 cm (27 in.) in the west to 73.7 cm (29 in.) in the east of the Turkey Creek Basin. Because more than half of annual rainfall occurs during the growing season (May-August), most of this source of water is made readily available for crop consumption. During the spring and summer months rainfall is delivered through localized thunderstorms, so that uniform distribution over the watershed is unlikely.

2.5.1 Water Supply

Basin-wide water budgets have been calculated for the Big and Little Blue watersheds of southeast Nebraska. Turkey Creek comprises only a minor portion of the Big Blue watershed, but the general characteristics of water storage and movement are similar. The major difference between Turkey Creek and the larger basins is that ground water supplied to the stream as baseflow appears in the lower half, and to a much smaller degree. Although ground water moves across the Turkey Creek Basin in a direction corresponding to surface flow, the deep basin aquifers rarely reach the streambed. The small amount of base flow contributing to Turkey Creek comes primarily from localized perched water tables and surficial deposits that cap the bedrock mounding of the southeast border.

Evapotranspiration accounts for loss of between 90-95% of all incoming precipitation in the region (Bentall and Shaffer, 1979; Nebraska Soil and Water Conservation Commission, 1968). For the most part, water is stored in the upper layers of soil and made available for uptake by vegetation. These upper layers are silt loams of relatively high permeability. Some soils have claypans found about 40 cm (17 in.) deep that will influence the generation of runoff when the surface layer becomes saturated. Water that infiltrates past crop roots is minimal in most years. An estimated three percent of total precipitation provides recharge to the deep basin aquifer (Nebraska Soil and Water Conservation Commission, 1968). Precipitation is most likely to become available for recharge during the early spring and late fall, when the ground is not frozen and crops are not developing (Keech and Dreeszen, 1968).

Surface runoff amounts to between 6-9% of total precipitation. Analyses of flow records for the Big Blue River Basin indicate that surface runoff contribution to streamflow is quite variable, with much of it occurring as flood flow (Nebraska Soil and Water Conservation Commission, 1968). Likewise in Turkey Creek, baseflow plays a minor role in contribution to annual volumes. During summer months the western half of Turkey Creek Basin is dry, except during and immediately following thunderstorms. Standing water may be evident throughout the middle portion of the creekbed and flow gradually picks up as the creek enters Saline County. Estimated average runoff across the basin ranges between 5.0-6.3 cm (2.0-2.5 in.) annually (Nebraska Soil and Water Conservation Commission, 1968)

Very little surface water is used for irrigation or domestic purposes. In the Turkey Creek Basin less than three percent of irrigation water was drawn from surface sources in 1964 (Nebraska Soil and Water Conservation Commission, 1968). Although surface water rights to Turkey Creek have been in existence for many years, creek water used for irrigation is used as a last resort. Turkey Creek water is used for livestock and may be diverted to small impoundments along flowing stretches. Flow into Turkey Creek is augmented by small amounts of irrigation return water. As the cost of pumping ground water for irrigation rises, more efficient irrigation and recycling methods have cut back the amount of runoff to the creek.

Generally, ground water available in sufficient supplies for irrigation lies at depths of between 18.3 - 30.5 m (60-100 ft). Because of intense development of irrigation from ground water over the last 35 years, declines in water levels of over 9 m (30 ft) have occurred in the western half of Turkey Creek Basin (Johnson and Pederson, 1982). An estimated 97% of all irrigation water is drawn from underground sources in the Big and Little Blue River Basins (Bentall and Shaffer, 1979). In Clay and Fillmore counties, where Turkey Creek is dry or standing still during much of the summer growing months, ground water provides 100% of the irrigation water. In Saline County more surface water is available due to base flow provided by shallow localized aquifers. Here, ground water provides approximately 88% of total irrigation needs (SCS, unpublished) on a county-wide basis, where other large surface sources exist.

An estimate of 0.35 cms (12.5 cfs) baseflow for Turkey Creek was made by observing hydrographs during the dry season from 1952-1974 (Nebraska Natural Resources Commission, 1983). This accounts for approximately 15% of the average annual flow at the gage near Wilber. This compares favorably with estimates of streamflow ground-water components of the Big and Little Blue River Basins at 20-30% (Bentall and Shaffer, 1979; Nebraska Soil and Water Conservation Commission, 1968).

2.5.2 Water Quality

Surface water quality of Turkey Creek is variable throughout the year. Since only a certain length of the creek is perennial, surface water is used only for limited purposes. Generally, it is silty even at low flow conditions. For the Big Blue River Basin as a whole, the Nebraska State Department of Health suggests that water quality is best in late winter and early spring, before spring runoff occurs.

Ground-water quality is generally adequate for irrigation purposes. Localized problems exist throughout the basin in terms of use for human consumption. Along the southeastern border of the Turkey Creek Basin, Quaternary deposits are relatively thin. Wells drilled into the lower extents of these layers, or the Dakota Sandstone below, may yield water as a mixture from both strata, becoming too mineralized for intended uses (Emery, 1966). Generally, water of poorer quality is found in areas of lower transmissibility. Most of the water extracted from Quaternary deposits is relatively hard, ranging between 140 - 200 ppm hardness as calcium carbonate. In general, the water contains less than 400 ppm of dissolved minerals (Keech and Dreeszen 1968).

2.5.3 Irrigation Water

The development of irrigation has been extensive since the early 1950's, when 98% of both Clay and Fillmore counties were dryland farmed. In 1984 approximately 50% of total land in both counties is irrigated. Due to large areas where ground water is inaccessible for irrigation, Saline County has approximately 22% of total acreage developed. Since 1962 irrigated acreage has increased almost linearly in Clay and Fillmore counties. By averaging the statistics of both counties, an average percentage of land devoted to irrigated agriculture for the study period was determined to be 44% of total land (statistics from Nebraska Natural Resources Commission, 1983 and Nebraska Dept. of Agriculture, 1983).

Within the Turkey Creek Basin there are two large blocks of land that cannot support irrigation development (Figure 2.2). These areas are exclusively dryland farmed. Due to bedrock mounding in both areas, water yielding Quaternary deposits are too thin or non-existent. This accounts for approximately 28% of the total basin area. Irrigated fields are distributed uniformly throughout the rest of the basin.

During the study period, irrigation water was applied almost entirely to corn acreage. Timing of irrigation events during the growing season depends on soil moisture depletion and current meteorologic conditions. Crop water requirements are calculated and forecasted on a daily basis. Normally, water is applied to crops 3-4 times per growing season, depending on seasonal meteorologic conditions. Water is applied assuming an efficiency factor that changes for each delivery system. The two basic types of systems are gravity flow and sprinkler. Of these, the sprinkler system is more efficient and is replacing gravity flow systems at a rate of about five percent per year, due to increased pumpage costs resulting from ground-water depletion (Mike Raabe, SCS, personal communication, 1984). In 1984 gravity flow and sprinkler systems number about equal. During the study period a 2:1 ratio was assumed, respectively.

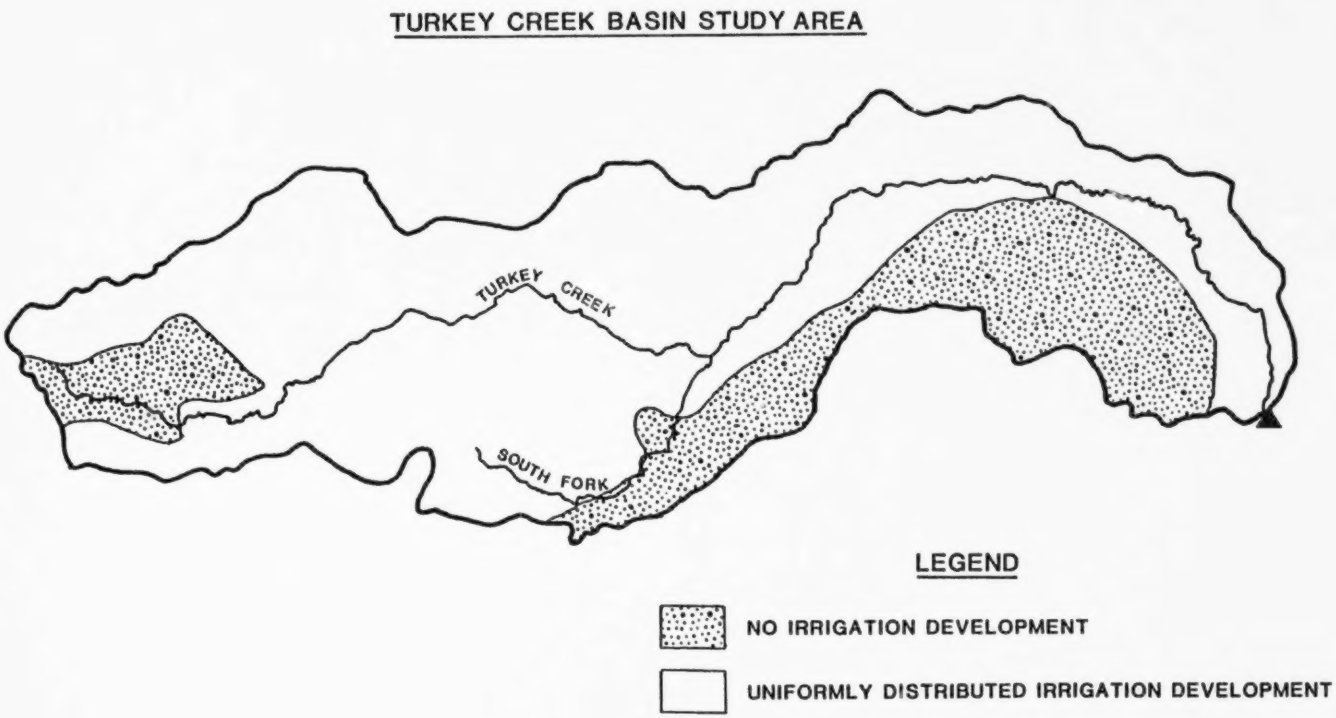

TURKEY CREEK BASIN STUDY AREA
TURKEY CREEK
SOUTH FORK
LEGEND
NO IRRIGATION DEVELOPMENT
UNIFORMLY DISTRIBUTED IRRIGATION DEVELOPMENT

Figure 2.2 Development of irrigation in Turkey Creek Basin.

SECTION 3

AVAILABILITY AND SELECTION OF TIME SERIES DATA

3.1 HSPF DATA AND TIME SERIES REQUIREMENTS

Hydrologic and sediment simulation with HSPF requires the following time series data:

1. precipitation
2. potential evaporation
3. streamflow (for comparison with simulated results)
4. water temperature
5. sediment (for comparison with simulated results)
6. air temperature
7. wind speed
8. solar radiation
9. dewpoint temperature

Of these, air temperature, wind speed, solar radiation, and dewpoint temperature are used in the HSPF snowmelt calculations. In the Turkey Creek Basin snow was simulated and all nine times series were required.

3.2 AVAILABLE DATA

There are no meteorologic stations pertinent to HSPF application located within the Turkey Creek Basin. Daily rainfall stations exist within the basin providing guides for meteorologic segmentation, but the closest hourly recording rainfall station is located in Crete, approximately 5 km (3 mi.) northeast of the watershed. All other meteorologic data required for HSPF simulation, except solar radiation values, are collected at Crete. In addition, daily evaporation and wind measurements are made at Clay Center, 11 km (7 mi.) west of the watershed. Only one streamgage exists on Turkey Creek and is located near Wilber. This gage marks the downstream end of the study basin.

Ten years of data were collected for each time series. The calibration and verification periods were chosen by examining hourly precipitation records from Crete. A three year calibration period was chosen to simulate one wet, one normal, and one dry year. This was best represented by data collected between 1978-1980. The verification period was also chosen using the same criteria, resulting in use of the time period immediately preceding calibration, 1975-1977. Due to lack of suspended sediment data for Turkey Creek, no other data requirement restrictions were imposed on selection of the simulation period.

3.3 SELECTION OF DATA FOR MODELING

3.3.1 Precipitation

One hourly recording precipitation station was chosen to represent rainfall across the Turkey Creek Basin. It is located in Crete, just beyond the northeast basin boundary. No other recording stations lie in the vicinity, the closest located approximately 30 km (18 mi.) to the north. The station at Crete began recording hourly values in July 1972. This determined the earliest point in time that simulation could begin, utilizing hourly data.

Missing data were filled in by comparing hourly recorded rainfall values at Lincoln WSO (for storm distribution) and the value recorded at the Crete daily precipitation station (for the daily total). Although hourly rainfall gages tend to record different totals over a 24 hour period than daily gages, the impact was assumed to be minor for the few missing days substituted during the 10-year period.

Turkey Creek Basin stretches almost 80 km (49 mi.) in an east-west direction, with variable average annual rainfall occurring along its length. The long term average annual rainfall computed at Crete is 71.9 cm (28.3 in.), while at Clay Center it is 59.4 cm (23.4 in.). Long term average annual rainfall values were plotted on a map for stations surrounding the Turkey Creek watershed. Rainfall isopleths were drawn and representative values across the basin were determined. Although only one rainfall gage could be used to represent the entire basin, this variability was accounted for during the simulation (defined in Section 4).

3.3.2 Pan Evaporation

Mean annual potential evapotranspiration for the Turkey Creek Basin can be derived from pan evaporation measurements. Stations at Crete and Clay Center lie at either end of the watershed and have collected data for the entire study period. Short stretches of missing data occurred at both stations, usually at non-coincident times. Missing data were filled in by using the value recorded at the opposite station. When both stations failed to report values on the same day, an average of the preceding and following day were filled in. During the long winter periods when no data were collected at either station, average monthly values were substituted with computed lake evaporation values provided by the National Weather Service for Lincoln and Grand Island, Nebraska. Examination of lake and pan evaporation data indicate that 0.70 should be used as the pan coefficient for this basin (U.S. Dept. of Commerce, 1968).

3.3.3 Streamflow

There is one streamgage measuring flow on Turkey Creek, located near Wilber. It is maintained and operated by the USGS. The gage is not located at the mouth of Turkey Creek, but approximately 25 km (15 mi.) upstream of the confluence with the Big Blue River.

3.3.4 Water Temperature

No long-term water temperature data exist for Turkey Creek. Measurements made on the Big Blue River near Crete were obtained from the USGS to be used as a surrogate for the temperature factor in the sand transport algorithm of HSPF. The drainage area of the Big Blue River above Crete is approximately six times larger than Turkey Creek. The basin extends 60 km (37 mi.) to the west and 45 km (28 mi.) to the north beyond the study basin boundary. Besides the longer residence time in the more extensive channel system, Big Blue River water also passes through a number of reservoirs before reaching Crete. Water temperatures will not be identical in the two basins, but no other data is available for better representation.

3.3.5 Sediment

No sediment data have been collected on Turkey Creek except for the results of sporadic sampling performed by the USGS.

3.3.6 Air Temperature

Air temperature was collected at Crete for the entire study period. Missing values were filled in by substitution with the closest neighboring station, located also in Crete.

3.3.7 Wind Speed

Wind data were collected at Crete and Clay Center. Missing values were replaced by measurements at the opposite station. If values were missing at both locations, the previous and following readings were averaged. Long term missing data for the winter months were taken from the nearest station providing year-round values, at Lincoln.

3.3.8 Solar Radiation

Solar radiation data for Ames, IA were collected for the study period. Measurements made at Lincoln, NE were first obtained and found to be lacking in continuity. Because the data from Ames were readily available and the fact that both locations lie on approximately the same latitude, Ames data were considered the best alternative. By applying the appropriate compensating adjustment factor for long term regional trends, Ames solar radiation data should provide representative values.

3.3.9 Dewpoint Temperature

Daily minimum temperature recorded at Crete was substituted for dewpoint temperature.

3.4 QUALITY OF DATA

Most of the data used in the Turkey Creek simulation project had been compiled and stored on the Hydrologic Information Storage and Retrieval System (HISARS) at the University of Nebraska in Lincoln. Additional data were obtained from the USGS and National Climatic Center in Asheville, NC.

Missing data were filled in by procedures described in the preceding section. In some cases reported measurements were accumulated over two or more days. Values were then distributed evenly during the affected time period. Nebraska is located such that winter temperatures remain below freezing for extended periods and winter measurements of evaporation, temperature, and wind are discontinued at nearby stations. The replacement of long term missing data with values from less representative sources will alter the response of the simulation to some extent. Air temperature data were supplied by HISARS as measured at Crete. Lack of measurements recorded for winter months required an alternate source. Measurements were made in Crete during these months and reported by the National Weather Service. These values were used to fill in missing HISARS values. Comparison of measurements reported by both sources for summer months revealed consistently different maximum and minimum daily values. No attempt was made to compare long-term summer temperature averages of the two stations since the air temperature time series is used exclusively for snow simulation during the winter months. Streamflow data reported by the USGS were described as fair except for the winter period, which were poor. They also remark that many diversions exist above the gage for irrigation. Although diversions exist, irrigation return flow helps to mitigate their effect during the spring and summer seasons.

3.5 DATA TIME SERIES SUMMARY

Data were collected for the application of HSPF to simulate the hydrologic response of Turkey Creek from stations surrounding the basin. A map of the Turkey Creek watershed with relevant hydrometeorologic stations is provided in Figure 3.1. Stations at Crete, approximately 5 km northeast, and Clay Center, 11 km west of the basin boundary, provide all the m meteorologic data required except solar radiation. Only one streamgage exists on Turkey Creek, located near Wilber. The drainage area above this gage is 1,191 sq. km (460 sq. mi.).

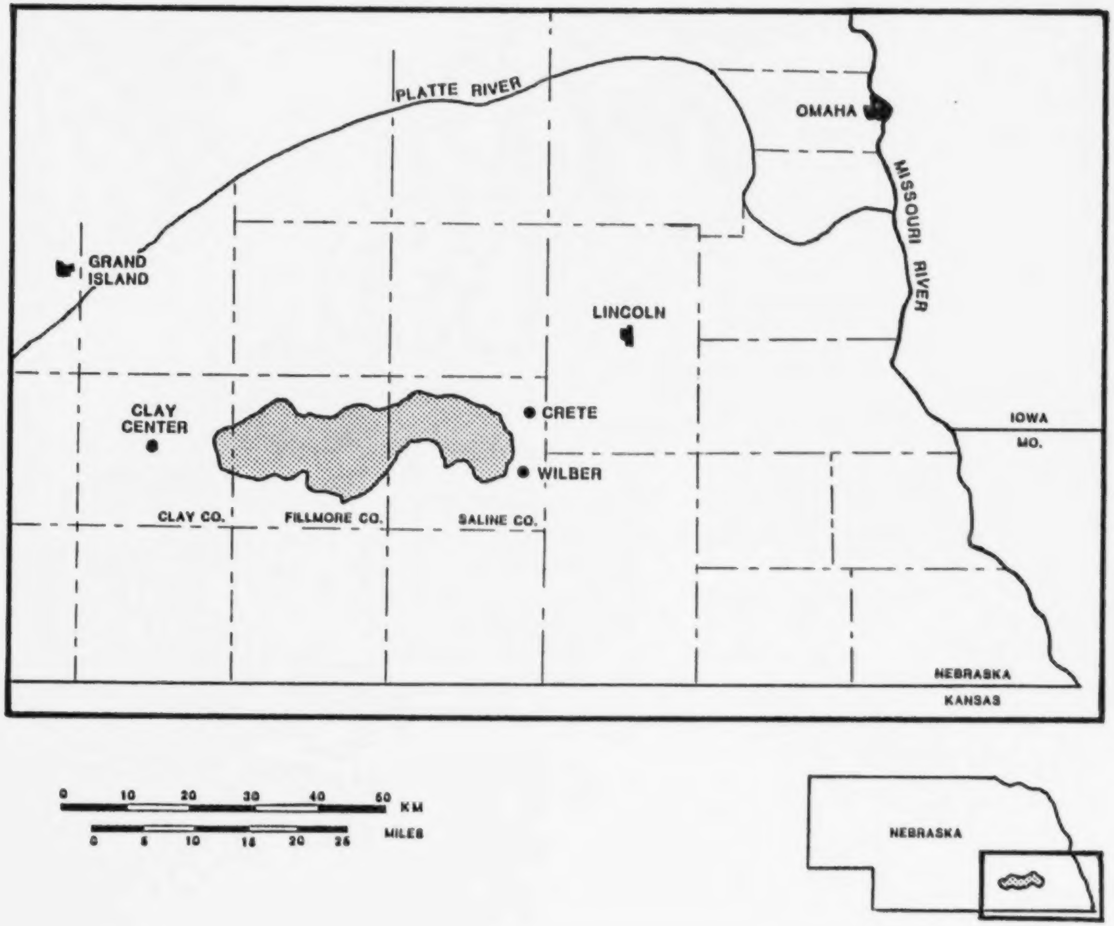

PLATTE RIVER
OMAHA
MISSOURI RIVER
GRAND ISLAND
LINCOLN
CLAY CENTER
CRETE
WILBER
CLAY CO.
FILLMORE CO.
SALINE CO.
IOWA
MO.
NEBRASKA
KANSAS
0 10 20 30 40 50 KM
0 5 10 15 20 25 MILES
NEBRASKA

Figure 3.1 Location of hydrometeorologic stations used in Turkey Creek simulation.

SECTION 4

WATERSHED SEGMENTATION FOR HSPF APPLICATION

4.1 PERVIOUS LAND SEGMENTATION

The segmentation of the watershed into pervious land segments (PLS's) for simulation by HSPF is based on evaluation of the following factors:

1. meteorologic patterns
2. soils characteristics
3. land use/cropping practices

4.1.1 Meteorologic Patterns

Long-term average annual precipitation patte[illegible] southeast Nebraska indicate that there is more than a 6 cm difference in rainfall at either end of the Turkey Creek watershed. To account for this substantial difference, the basin should be segmented on a meteorologic basis. Figure 4.1 provides a map of the basin with precipitation isopleths drawn according to long-term averages reported for 35 local stations.

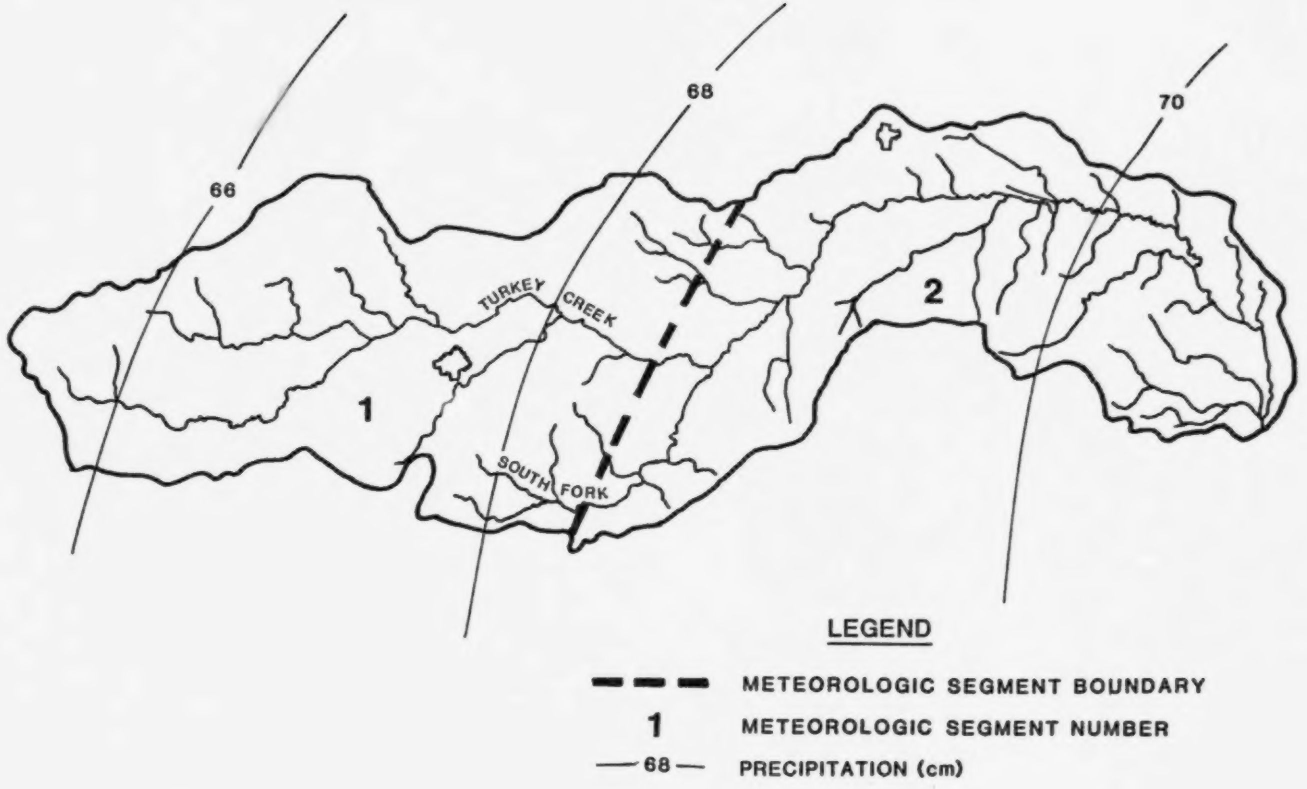

66
68
70
TURKEY CREEK
SOUTH FORK
1
2
LEGEND
METEOROLOGIC SEGMENT BOUNDARY
1 METEOROLOGIC SEGMENT NUMBER
—68— PRECIPITATION (cm)

Figure 4.1 Preliminary segmentation of Turkey Creek Basin to account for variability in precipitation patterns.

Segmentation provided two meteorologically distinct regions, dividing the basin into halves. Both segments must be represented by the same rainfall gage at Crete, with appropriate representative multiplication factors.

4.1.2 Soils Characteristics

The three major soil groups of the Turkey Creek Basin are distributed uniformly within the watershed. No segmentation need be based on this distribution.

4.1.3 Land Use

Land use affects the hydrologic response of a watershed by influencing infiltration, surface runoff, and water losses from evaporation or consumptive use by vegetation. The movement of water through the system, and subsequent erosion loss, is affected entirely through management of vegetation; be it crops, pasture, or forest. The Turkey Creek Basin is a region extensively devoted to agriculture, where lack of soils management has resulted in some erosion problems in the more rolling eastern half.

The distribution of each crop and the pasture land is uniform throughout the basin, except for the two large areas devoted entirely to dryland practices (delineated in Figure 2.2). Although these areas totally exclude irrigated crops, no new land management program is introduced to the watershed. This results in a higher percentage of dryland crops contributing runoff to stream reaches fed by these areas. The distribution of crops was maintained as uniform across the basin for the

HSPF application.

4.1.4 Final Pervious Land Segmentation

The Turkey Creek Basin has been divided into pervious land segments based on land use differences within two meteorologically distinct regions defined by rainfall isopleths in Figure 4.1. The resulting eight PLS's are defined below with their attendant areal coverage in percent of total land area. Upland refers to the upper end of the basin, defined by meteorologic segment 1, and lowland refers to the lower end of the basin, defined by meteorologic segment 2:

1.	Upland Corn	13.0%
2.	Upland Sorghum	9.8%
3.	Upland Wheat	9.8%
4.	Upland Pasture	8.2%
5.	Lowland Corn	10.9%
6.	Lowland Sorghum	16.4%
7.	Lowland Wheat	20.1%
8.	Lowland Pasture	11.8%

4.2 IMPERVIOUS LAND SEGMENTATION

Only a minor portion of the study area is devoted to urban areas with associated impervious land. For this reason, the hydrologic response for these areas will have a negligible affect on the response of the whole system. No impervious land segments have been included in the modeling effort.

4.3 CHANNEL SEGMENTATION AND NETWORK

Stream reach segmentation requires consideration of river travel time, river-bed slope continuity, and entry points of major tributaries. The following sections describe the method and data used to segment Turkey Creek into reaches.

4.3.1 Channel Characteristics

The hydraulic routing algorithms in HSPF are most accurate when flow time through each reach approximates the simulation time step. A 2-hour time step was chosen for routing, which results in approximately 40 reaches for greatest simulation accuracy. Because the calibration was based on comparison of average daily flow values and to accommodate computer run-time and cost constraints, the number of reaches was reduced and reach lengths were increased. The use of longer reaches tends to reduce and spread out instantaneous peak flows, with minimal impact on average daily values. Use of long reaches is common practice in modeling large watersheds.

Channel slope does not change noticeably throughout the entire length of the creek. There are no abrupt changes in elevation or backwater pools of significant size. Reach boundaries could not be delineated by points of slope discontinuity.

The method employed to divide the creek into reaches was based on four considerations. The first was to keep each reach of approximately the same length. The second was to keep the contributing land areas to each reach approximately the same size. The third was to roughly match the meteorologic segmentation discussed earlier. The last consideration involved segregation of areas subject to different hydrologic supply mechanisms. This last point results in grouping all reaches receiving ground water from the bedrock mounded area along the southeast boundary of the basin into one segment. The channel system that lies upstream of the bedrock mounding constitutes another segment.

4.3.2 FTABLE Definition

The hydraulic characteristics of each reach must be specified in an FTABLE for use in the HSPF input sequence. FTABLEs specify values for surface area, reach volume, and discharge for a series of selected average depths of water in the reach; intermediate values are interpolated.

FTABLEs were produced by an auxiliary computer program requiring inputs of reach dimensions, and Manning's n values for both the channel and the floodplain (Table 4.1).

Channel dimensions for the four main-channel reaches were developed from cross-section data collected by the Nebraska Water Resources Center. Cross-sections were measured at nine points along the channel, above the streamgage.

4.3.3 Reach Network Summary

The resulting study plan employs a network of five reaches, four of which are connected in series. The other reach enters the main channel at the approximate halfway point. A map of the reaches and their attendent contributing land areas

TABLE 4.1 REACH CHARACTERISTICS OF THE TURKEY CREEK BASIN SIMULATION NETWORK

Reach	Length km (mi.)	Average Slope %	Bottom Width m (ft)	Bankfull Width m (ft)	Channel Height m (ft)	Flood-plain Slope %	Channel n	Flood-plain n
1	31.4 (19.5)	.112	2.4 (8.)	3.0 (10.)	1.5 (5.0)	.001	.045	.090
2	20.9 (13.0)	.109	3.0 (10.)	9.2 (30.)	1.8 (6.0)	.001	.045	.090
3	23.3 (14.5)	.098	5.5 (18.)	15.2 (50.)	1.5 (5.0)	.001	.045	.090
4	25.4 (15.8)	.132	6.1 (20.)	15.2 (50.)	2.2 (7.3)	.001	.045	.090
5	32.2 (20.0)	.102	7.3 (24.)	21.4 (70.)	2.3 (7.5)	.001	.045	.090

appears in Figure 4.2. The dashed lines represent the boundaries of the contributing land areas draining into each channel segment. The FTABLEs corresponding to each reach used for simulation are shown in Table 4.2.

4.4 CONNECTIVITY OF LAND SEGMENTS AND STREAM REACHES

For the most part, crops are grown uniformly distributed throughout the Turkey Creek Basin. The exception lies in the two large blocks of land devoted entirely to dryland farming, due to the lack of available ground water for irrigation. These areas support sorghum and wheat exclusively. Because of the relatively large dryland area in the eastern portion of the basin, the crop mix between east and west varies slightly. This is reflected in the areal distribution of land uses contributing to each reach. The values used for simulation are provided in Table 4.3.

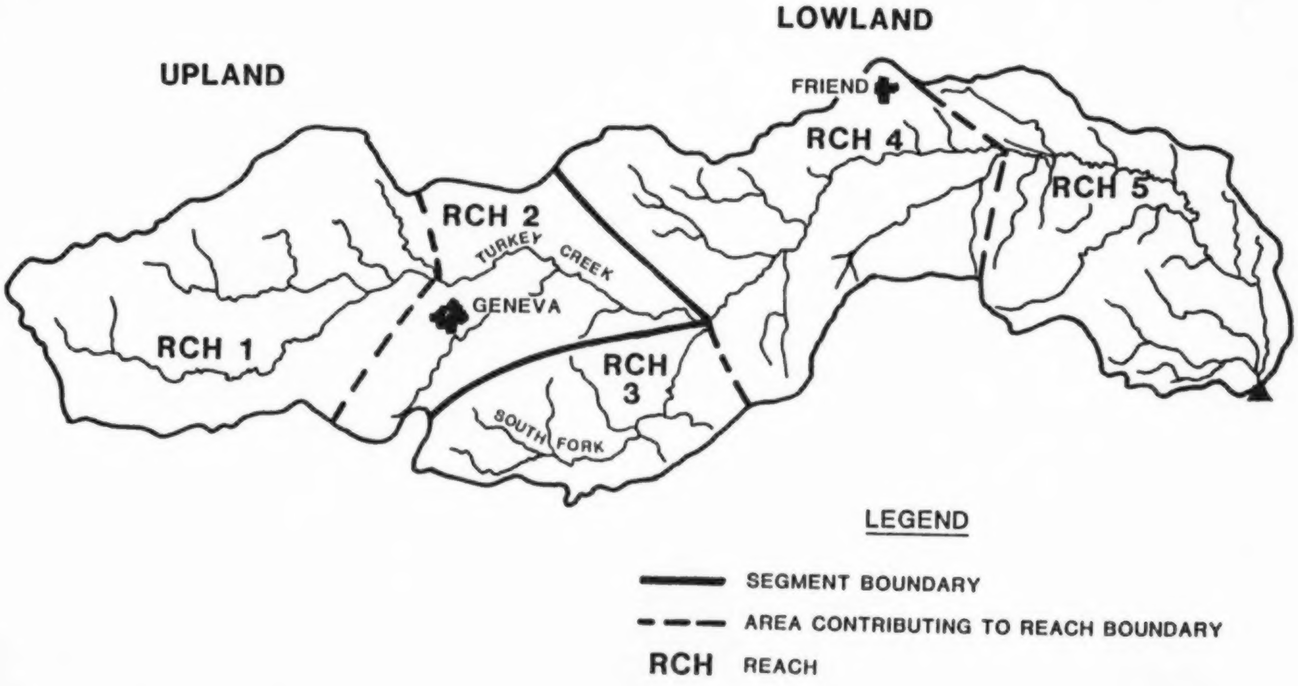

UPLAND
LOWLAND
FRIEND
RCH 1
RCH 2
RCH 3
RCH 4
RCH 5
TURKEY CREEK
GENEVA
SOUTH FORK
LEGEND
SEGMENT BOUNDARY
AREA CONTRIBUTING TO REACH BOUNDARY
RCH REACH

Figure 4.2 Land area contributions to the reach network.

TABLE 4.2 FTABLES USED IN FINAL INPUT PARAMETER SET

```
  FTABLE      1
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .417     1.970     .4104     .0336    3363.0
      .833     3.939    1.6414     .3401    3503.7
     1.250     5.909    3.6932    1.0029    2673.4
     1.667     7.879    6.5657    2.1601    2206.7
     2.083     9.848   10.2388    3.9169    1901.5
     2.500    11.818   14.7727    6.3496    1683.8
     3.333    15.758   26.2626   13.7191    1389.8
     4.167    19.697   41.0354   24.8762    1197.6
     5.000    23.636   59.0909   40.4339    1060.5
     6.667  7902.427 4664.1445 1455.7449    3323.5
     8.333 15781.21526400.3160 8809.5938    2175.7
    10.000 23660.00059268.187025739.8710    1671.7
  END FTABLE  1

  FTABLE      2
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .500     3.939     .9848     .2582    2748.7
     1.000     7.879    3.9394    1.6401    1743.8
     1.500    11.818    8.8636    4.8362    1330.6
     2.000    15.758   15.7576   10.4164    1098.3
     2.500    19.697   24.6212   18.8876     946.4
     3.000    23.636   35.4545   30.7153     838.0
     4.000    31.515   63.0303   66.1555     691.7
     5.000    39.394   98.4848  119.9569     596.0
     6.000    47.273  141.8182  195.0750     527.8
     8.000  6350.305 6539.3955 2646.1123    1794.2
    10.000 12653.33425343.039014703.4650    1261.2
    12.000 18936.36357152.727042212.5230     983.0
  END FTABLE  2

  FTABLE      3
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .417    23.434    8.5438    2.5570    2425.8
      .833    29.293   19.5286    8.7149    1626.8
     1.250    35.152   32.9545   18.4241    1298.6
     1.667    41.010   48.8216   31.9637    1108.9
     2.083    46.869   67.1297   49.6658     981.3
     2.500    52.727   87.8788   71.8726     887.7
     3.333    64.444  136.7003  131.1531     756.7
     4.167    76.162  195.2862  212.4435     667.4
     5.000    87.879  263.6364  318.2650     601.4
     6.667  5946.466 5292.7568 1939.3071    1981.2
     8.333 11805.05320085.1910 9700.7441    1584.9
    10.000 17663.63744642.430025501.8830    1270.9
  END FTABLE  3

  FTABLE      4
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .608     7.980    2.4272     .6704    2628.6
     1.217    15.960    9.7088    4.2575    1655.6
     1.825    23.939   21.8447   12.5543    1263.3
     2.433    31.919   38.8350   27.0398    1042.7
     3.042    39.899   60.6797   49.0301     898.5
     3.650    47.879   87.3788   79.7332     795.6
     4.867    63.838  155.3401  171.7318     656.7
     6.083    79.798  242.7189  311.3936     565.9
     7.300    95.758  349.5154  506.3909     501.1
     9.733  9416.16811922.3690 5243.6367    1650.7
    12.167 18736.57446174.898027845.7150    1203.9
    14.600 28056.988103107.09079139.5470     945.9
  END FTABLE  4

  FTABLE      5
 ROWS COLS ***
   13    4
     DEPTH      AREA    VOLUME     DISCH  FLO-THRU ***
      (FT)   (ACRES)   (AC-FT)     (CFS)     (MIN) ***
      .000      .000     .0000      .000       0.0
      .625    54.141   30.5556    9.0632    2447.1
     1.250    64.646   67.6768   30.2116    1626.3
     1.875    75.152  111.3636   62.5227    1293.1
     2.500    85.657  161.6162  106.3980    1102.8
     3.125    96.162  218.4344  162.5111     975.8
     3.750   106.667  281.8182  231.6245     883.3
     5.000   127.677  428.2829  412.0255     754.6
     6.250   148.687  601.0101  653.9448     667.2
     7.500   169.697  800.0000  943.5906     602.7
    10.000 12290.90816375.7580 5798.5674    2050.3
    12.500 24412.12162254.547027604.8010    1637.3
    15.000 36533.336138436.34076674.9370    1311.6
  END FTABLE  5
```

TABLE 4.3 CONTRIBUTING LAND AREAS TO EACH REACH

		Contributing Land Areas sq. km (sq. mi.)					
PLS	Land Use	RCH 1	RCH 2	RCH 3	RCH 4	RCH 5	Total
1	Upland Corn	87.3 (33.7)	68.1 (26.3)				155.4 (60.0)
2	Upland Sorghum	80.3 (31.0)	36.3 (14.0)				116.6 (45.0)
3	Upland Wheat	80.3 (31.0)	36.3 (14.0)				116.6 (45.0)
4	Upland Pasture	61.9 (23.9)	35.2 (13.6)				97.1 (37.5)
5	Lowland Corn			28.3 (10.9)	64.8 (25.0)	37.0 (14.3)	130.0 (50.2)
6	Lowland Sorghum			39.6 (15.3)	79.0 (30.5)	77.2 (29.8)	195.8 (75.6)
7	Lowland Wheat			48.2 (18.6)	96.6 (37.3)	94.3 (36.4)	239.1 (92.3)
8	Lowland Pasture			29.0 (11.2)	60.1 (23.2)	52.1 (20.1)	141.2 (54.5)
	Total	309.8 (119.6)	175.9 (67.9)	145.0 (56.0)	300.4 (116.0)	260.6 (100.6)	1191.7 (460.1)

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